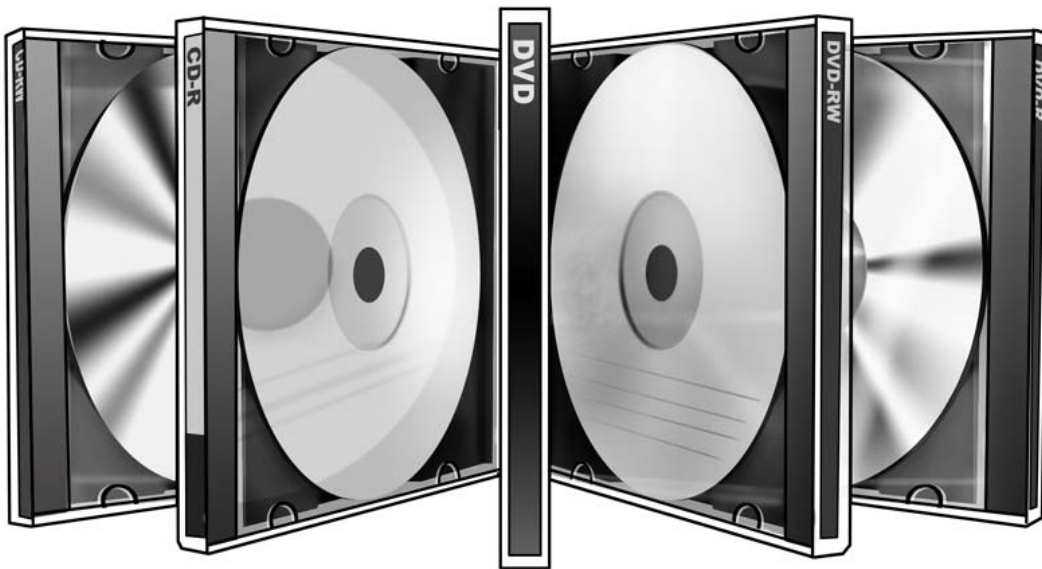


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Information Technology:

Care and Handling for the Preservation of CDs and DVDs — A Guide for Librarians and Archivists

Fred R. Byers



NIST

National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

Information Technology:
**Care and Handling for the Preservation of
CDs and DVDs — A Guide for Librarians
and Archivists**

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Preface

The Convergent Information Systems Division (CISD) of the Information Technology Laboratory (ITL) at the National Institute of Standards and Technology (NIST) has assembled this guide for librarians, archivists, Government agencies, and other end users responsible for the long-term preservation of optical discs, notably CD and DVD.

This document provides care and handling guidelines with an explanation of factors leading to those guidelines. The intent is to provide advice that will enhance the lifetime, preservation, and usefulness of CD and DVD media for both frequently accessible and archival (i.e. long-term or extended-term) storage environments.

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Quick Reference Guide for Care and Handling

For long-term storage or archival purposes of recordable (R) discs, it is recommended to use recordable (R) discs that have a gold metal reflective layer.

Do:

1. Handle discs by the outer edge or the center hole.
2. Use a non solvent-based felt-tip permanent marker to mark the label side of the disc.
3. Keep dirt or other foreign matter from the disc.
4. Store discs in plastic cases specified for CDs and DVDs, store upright (book style).
5. Replace discs into jewel cases or video DVD cases immediately after use.
6. Let discs acclimate to changed environmental conditions by leaving the disc in its packaging (or case) to buffer the effects of the environmental changes.
7. Wait to open a recordable disc package until you are ready to record data on the disc.
8. Store in a cool, dry, clean air, dark environment.
9. Remove dirt, foreign material, fingerprints, smudges, and liquids by wiping with a clean cotton fabric in a straight line from the center of the disc toward the outer edge.
10. Use CD/DVD cleaning detergent, isopropyl alcohol or methanol to remove stubborn dirt or material.
11. Check the disc surface before recording.

Do Not:

1. Touch the surface of the disc.
2. Bend the disc.
3. Use adhesive labels.
4. Store discs horizontally for a long time (years).
5. Open a recordable optical disc package if you are not ready to record.
6. Expose discs to extreme heat or high humidity.
7. Expose discs to extreme rapid temperature or humidity changes.
8. Expose CD-R or DVD-R/+R discs to prolonged sunlight or other sources of UV light.
9. Write or mark in the data area of the disc (area where the laser reads).
10. Clean in a circular direction around the disc.

CDs especially, Do not:

1. scratch the label side of a CD.
2. use a pen, pencil, or fine tip marker to write on CDs.
3. write on CDs with markers that contain solvents.
4. try to peel off or re-position a label on a CD.

General recommendation for long-term storage conditions

Archival Storage Facility - Recommendation for storing CDs and DVDs together		
Media	Temperature	Relative Humidity (RH)
CD, DVD	Less than 20°C (68°F), greater than 4°C (39°F)	20% to 50% RH
A temperature of 18°C and 40% RH would be considered suitable for long-term storage.		
A lower temperature and RH is recommended for extended-term storage.		

1. Introduction

1.1 Scope of this guide

This document describes the care and handling of optical discs (CD-ROM, CD-R, CD-RW, DVD-ROM, DVD-RAM, DVD-R, DVD-RW, DVD+R, and DVD+RW) for use by librarians and archivists in government, academia and industry to insure maximum reliability and longevity of content stored on these formats. The work represents an overview of resources from the industry's accumulated knowledge base and NIST studies. The document provides guidelines that will maximize the lifetime and usefulness of optical discs by minimizing chances of information loss due to disc deterioration or physical handling. Topic areas include: preventing premature degradation; preventing information loss; CD and DVD structure; life expectancy; and conditions that affect optical discs.

This guide concentrates on the preservation of current optical disc technology, specifically CD and DVD media. While specific care and handling of optical discs collections will enhance the longevity and usefulness of these discs, understanding and managing the differing types of discs can be confusing for those responsible for the long-term care and maintenance of them. Optical disc technology consists of three independent components – the optical disc, disc drive, and software. No component is expected to last forever. Information recorded on optical discs can become lost due to: physical deterioration or damage to the disc, software and disc drive obsolescence, lack of playback device, or playback device inoperability. The purpose of this guide is to provide information to help in preventing or reducing premature physical deterioration of, or damage to CDs and DVDs.

Care, maintenance, and preservation strategies of the disc drive device, associated hardware and software, as well as digital rights, legality, methods of making, sending, or receiving digital copies, including analog-to-digital conversion, are beyond the scope of this guide. Also, this document is not intended to imply a standard. It is a consensus from several sources on what is considered prudent care of CDs and DVDs.

1.2 Using the terms: Information, Content, and Data

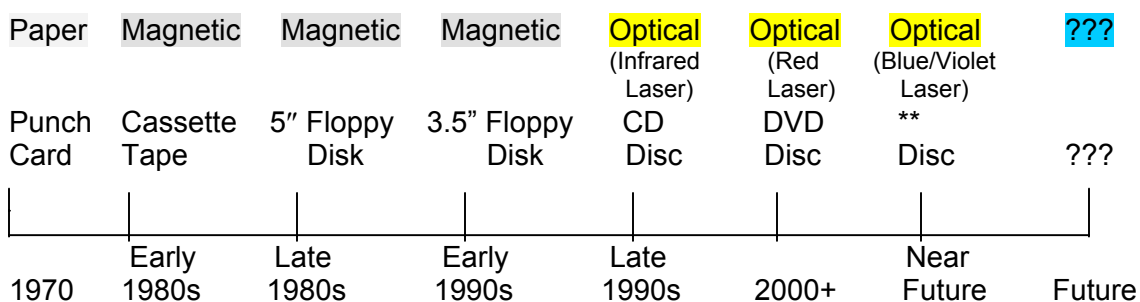
The terms “information” and “content” used throughout this document refer to audio, video, photographic images, graphics, animations, interactive games, computer applications, documents, files or data, and any other digital formats. “Data” will be viewed as smaller pieces of information from which “understandable information” is derived. The term “data” is used extensively throughout this guide to illustrate the bits recorded in the disc. These bits, or data, are interpreted as 1's and 0's by the optical disc drive. This eventually becomes “information” to the user, in all the interpreted forms listed above, following several manipulation steps by the software and hardware of a computer or playback system.

1.3 Optical media, magnetic tape, microfilm, and paper

With the proper care, microfilm and non-acidic paper can last for centuries, and magnetic tape, a few decades (Van Bogart 1995). Optical discs and digital magnetic tape are types of digital media; neither are as stable as microfilm or paper. Pre-recorded and write-once optical discs are more stable than magnetic tape. One disc type can last longer than another just as film types vary in years of usefulness. Temperature and humidity conditions can affect the length of time that a disc will be useful. Discs can be rendered useless in as little as a few days as a result of extreme environmental factors.

Technological advances will no doubt make current optical disc types obsolete within several years. If the current software used to interpret the data on optical discs becomes unavailable, a migration or emulation technology will be needed to access the data. Also, if the current disc-drive technology becomes unavailable (including backwards compatibility in future disc drives), the information on the discs will likewise be inaccessible. Film and paper are much more stable in this regard as the human language does not change as rapidly as computer software, hardware or the formatting of the media. For example “ink on paper” has been used for centuries, and film has not changed significantly over the years.

The importance of ensuring that information can be read by future generations cannot be overstated. It is vital that a preservation strategy be in place that guarantees the future sustainability of the collection, as far as possible. The computer user 'industry standard' for removable digital media to store data has changed considerably over the past few decades. Digital media that was used in as little as twenty years ago is already incompatible with most of today's systems. (TASI 2002) See Diagram 1.



** Blu-Ray Disc, Advanced Optical Disc, or other.

Diagram 1: User removable storage-media timeline
 Timeline illustrates the changes in common “removable” storage media
 (Technical Advisory Service for Images (TASI) 2002, extended)

1.4 An Introduction to CD and DVD Optical Media

CD is short for Compact Disc. DVD initially stood for Digital Video Disc, then Digital Versatile Disc, but more recently is often just “DVD” as an acronym that does not refer to anything. Both CDs and DVDs are optical media (optical discs). That means CDs and DVDs are media that use light technology (more specifically, laser light) for data retrieval. A laser light beam is focused into the CD or DVD by a disc drive to “read” the bits (data) in the CD or DVD. The disc drive also “writes” bits by focusing the laser beam into recordable CDs or DVDs. The laser “reads” and “writes” data starting from the center of the disc and going outward in a spiral direction toward the outer edge. A pre-groove is stamped in all blank recordable and rewritable CDs and DVDs to guide the laser as it writes.

CD-R, DVD-R and DVD+R discs are dye based recordable write-once discs. CD-RW, DVD-RW, and DVD+RW discs are phase-change recordable rewritable discs. DVD-RAM discs are also phase-change recordable rewritable discs but with “random access” much like a computer hard drive. CD-ROM and DVD-ROM discs are pressed and molded, not recordable, read-only discs.

2. Ensuring that your digital content remains available

Archivists and librarians place a strong emphasis on long-term preservation of content, while ensuring everyday usability. One of the challenges for librarians and archivists is to ensure availability of the digital content in their collection. Another challenge is keeping the medium of storage in as close to original condition as possible until the content on the medium is either no longer needed, or migrated to a newer technology as the medium becomes outdated.

Archiving, out of necessity, is becoming more of an on-going technological strategy to ensure continued, long-term access to stored collections (Kyong-Ho, NIST, 2002). This need for a technological strategy increases as increasingly more newly created content is created digitally (born digital), and with more content being converted from analog to digital. Content that has been converted from analog to digital format then becomes subject to keeping pace with the faster changing digital technologies. The importance of including proper handling of the digital media, as part of the strategy, increases as digital collections grow. (NDIIPP, Library of Congress, 2002)

CDs and DVDs have become the latest popular format for removable storage of increasingly more, and more types of digital content. Digital media has become increasingly popular in part because it can provide easier and faster access to content. It can also enable a wider and easier distribution of content by its ability to store the equivalent of, for example, reams of documents, or hundreds of songs on one tape or one disc respectively. These factors also contribute to the growing analog-to-digital conversions by the scanning of existing documents, books, periodicals, photographs and graphics, and the conversion of music or moving images. Access to a particular file,

song, video clip, document, record, or photograph, within collections of files can be accessed even faster on optical discs than on magnetic tape. There are potential trade-offs however in analog-to-digital conversions. Converting analog content to digital content can have an initial loss of quality by the digital representation of an analog original due to sampling rates, compression algorithms, or the quality of recording during the conversion. These issues vary and each should be considered when performing analog-to-digital conversions. Details of these issues will not be addressed in this document.

Digital original (born digital) content can represent reading materials, audio, video, photographs, graphic arts, x-rays, games, records, reference data...and so on. Digital copies of digital originals maintain the same quality as the original. Digital copies of the first digital copy of an analog original will maintain the quality of the first digital copy of the analog original. Digital copies of digital copies will also maintain the same quality as the original digital copy. This feature provides an opportunity for ensuring the availability of the quality of the original CD, DVD, or other digital source, assuming the content has not been altered by system software or hardware.

The ability to have copies made of equal quality (digital-to-digital) means that it is possible and recommended to store copies of digital collections (preferably the originals) in a different environment from frequently accessible copies. Since the frequently accessed copy will have essentially the same quality as the archived copy (or original), the archived media will only be needed for inspections, making additional copies, or migrating to new media. Archival digital copies should also be stored in separate locations from the accessible copies to prevent information loss due to disaster, theft, or mishandling.

If a budget precludes separate locations, keep multiple copies at the same location. The original can be designated as “archival” and other copies can be designated “accessible”. If the original is an analog format, designate it as archival adding the original digital version copy along with it. Archiving both the analog original and the digitally converted copy will give the benefits of both for future access. The digital version may become a more useful representation of the original quality of the analog original, if the analog original deteriorates before the digital version. Likewise if the digital version deteriorates first, newer copies if needed, can be made from the analog original. Even if your storage facility does not meet recommended guidelines, keep the originals isolated and protected, and use a copy for everyday access.

Archived copy - Limited use	Frequently accessible copy - Multiple use
<ul style="list-style-type: none"> • Store in a controlled environment and at a separate location, if possible, from the frequently accessible copy. • Store in environmental conditions recommended for archival storage. 	<ul style="list-style-type: none"> • Store for easy access • Check disc visually for damage or contamination after handling. • Store in environmental conditions similar to usage conditions.

3. CD and DVD: Disc Structure

CDs and DVDs employ the same basic materials and layers but are manufactured differently. A DVD is actually like two thin CDs glued together. A CD is read from and written to (by laser) on one side only. A DVD can be read from or written to on one side only or both sides, depending on how the disc was manufactured. Recordable (R, RW, RAM) DVDs can be manufactured with one recording layer on both sides. Pre-recorded (ROM) DVDs can be manufactured with one or two recorded layers on both sides.

Disc structure tables:

Table 1, Basic disc structure layers (CD/DVD ROM).....	page 7
Table 2, Basic disc structure layers (CD/DVD R, RW, RAM).....	page 7
Table 3, Data/Metal layers (CD/DVD).....	page 8
Table 4, Dye types (CD-R).....	page 9

CD-ROM (Single-sided)	DVD-ROM (Single-sided)	DVD-ROM (Single-sided)	DVD-ROM (Double-sided)	DVD-ROM (Double-sided)
(All CD-ROMs are one-sided) One recorded layer	(One side) One recorded layer	(One side) Two recorded layers	(Both sides) One recorded layer per side	(Both sides) Two recorded layers per side
Label, optional	Label, optional	Label, optional	Label, optional (hub area only)	Label, optional (hub area only)
Lacquer	Polycarbonate	Polycarbonate	Polycarbonate	Polycarbonate
Metal	Center Adhesive	Metal (fully-reflective)	Metal	Metal (semi-reflective)
Polycarbonate	Metal	Center Adhesive	Center Adhesive	Adhesive
	Polycarbonate	Metal (semi-reflective)	Metal	Metal (fully-reflective)
		Polycarbonate	Polycarbonate	Center Adhesive
			Label, optional (hub area only)	Metal (fully-reflective)
				Adhesive
				Metal (semi-reflective)
				Polycarbonate
				Label, optional (hub area only)

Table 1: Basic Layers of CD-ROM and DVD-ROM
(Replicated discs for audio, video, computer use, or interactive games)

CD-R, CD-RW (Single sided)	DVD-R, DVD-RW, DVD+R, DVD+RW, DVD-RAM (Single sided)	DVD-R, DVD-RW, DVD+R, DVD+RW, DVD-RAM (Double sided)
CD-R/RW are one-sided, One recordable layer only	(One side) One recordable layer only	(Both sides) One recordable layer per side only
Label, optional	Label, optional	Label, optional (hub area only)
Lacquer	Polycarbonate	Polycarbonate
Metal	Center Adhesive	Recording/writing layer
Recording/writing layer	Metal	Metal
Polycarbonate	Recording/writing layer	Center Adhesive
	Polycarbonate	Metal
		Recording/writing layer
		Polycarbonate
		Label, optional (hub area only)

Table 2: Basic Layers of CD -R/-RW and DVD -R/-RW/+R/+RW/RAM
(Blank recordable discs for all applications as ROM discs listed above)

3.1 Polycarbonate substrate (plastic) layer

The polycarbonate substrate comprises most of the disc including the surface of the disc that is read by the laser (opposite the label side on CDs). It is on both sides of a DVD even if the DVD is a “single sided” disc with a label on one side. The polycarbonate (plastic) substrate layer provides the proper disc depth to maintain laser focus on the metal and data layers. It also provides the disc enough strength to remain flat. Anything in or on the polycarbonate layer that interferes with the ability of the laser to focus on the data layer will result in missing data as it is being read. Polycarbonate is a relatively soft plastic that will allow moisture (water or other liquids) to be absorbed. Fingerprints, smudges, scratches, dirt, dust, solvents, excessive moisture, and any other foreign material can interfere with the ability of the laser to read the data. Contact with any of the above should be avoided with the polycarbonate substrate (plastic) layer.

3.2 Data Layer

The data layer holds data as marks or conditions within the layer that either absorb or transmit the laser light as it is reflected back to the laser photosensor. The data and metal layers in a CD are very close to the top of the disc (label side). DVDs also have metal and data layers as CDs do, but these are located in the middle of the disc (See figures on pages 14, 17, 18). The type of layers used depends on whether it is a read-only (ROM) disc, write-once (R), or rewritable (RW, RAM) disc. Table 3 below shows the relationship between the data and metal layers and the disc type.

CD-	DVD-	Type	Data Layer	Metal Layer
CD-ROM Audio/Video and PC use	DVD-ROM Video/Audio and PC use	Read only	Molded	Aluminum (also Silicon, Gold or Silver in double layered DVDs)
CD-R	DVD-R DVD+R	Recordable (Write once only)	Organic Dye	Gold, Silver or Silver alloy
CD-RW	DVD-RW DVD+RW DVD-RAM	Rewritable (Write, erase, and re-write)	Phase-changing metal alloy film	Aluminum

Table 3: Disc type, Read/Record Type, Data Layer, and Metal Layer

3.2.1 Data Layer in ROM discs

(ROM discs are commercially available or made-to-order pre-recorded discs, also called “replicated” discs.)

CD-ROM, (Audio CD, Video CD, CD-i, CD+G, Computer applications)

DVD-ROM, (DVD-Video, DVD-Audio, Games, Computer applications)

For CD or DVD ROM type discs, the data is not actually a separate layer but is made an integral part of the inner surface side of the polycarbonate substrate as “pits” and “lands” during the molding process. The reflective metal layer is then applied and conforms to the molded polycarbonate substrate (See figures 1, 2, page 14). The metal layer in ROM discs is aluminum. For double-sided DVDs, the second reflective layer is gold, silver alloy, or silicon.

3.2.2 Data Layer in R discs

(CD-R, DVD-R, DVD+R (recordable, write once discs))

The recordable optical disc has its data recording layer sandwiched between the polycarbonate substrate and the metal layer (See Figures 7, 8, page 17). This layer is an organic dye. The dyes used in DVDs and CDs are the same basic types but those used in DVD discs are dyes patented by the manufacturer and the disc color does not indicate the dye type used. The dyes (in both CD and DVD) are photosensitive. Bits (marks) are written to the dye by a chemical change resulting from the laser light beam. This dye transformation can degrade over time making the data unreadable. Prolonged exposure to ultraviolet light, high relative humidity, or high temperature will accelerate the degradation.

The data layer in CD-R (recordable) discs consists of one of three basic dye types, each yielding a differing disc color appearance depending on the dye combined with the type of reflective metal used in the disc. If the label side of a recordable (R) disc does not have a printable surface, label attached, or some other protective layer, it will look the color of the metal used (silver or gold). The dye will not affect the color appearance of the metal from the label side of the disc. The other side (laser reading side) of the disc will have a color appearance as shown in Table 4 below.

Dye Type	Color appearance (Viewing the data side of the disc)		
	Actual Color	On Gold Metal	On Silver Metal
Phthalocyanine (thalo-sy-a-neen)	clear or very light green	gold or greenish gold	silver
Cyanine (sy-a-neen)	blue	green	blue
Azo (ay-zo)	dark blue or deep blue	dark green	dark blue or deep blue

Table 4: Dye Type and Color appearance – CD-R discs (recordable discs)

3.2.3 Data Layer in RW and RAM discs

(CD-RW, DVD-RW, DVD+RW, DVD-RAM (rewritable discs))

The rewritable optical disc data recording layer is also between the polycarbonate substrate and the metal layer (See Figures 9, 10, page 18). This layer is a phase-changing metal alloy film. This phase changing film is used both in CD and DVD rewritable discs. The bits (marks) are written to the film by the laser beam heating the film and causing a phase change (crystallization) where the bits are to be written. Dielectric layers on both sides of the film causes rapid cooling of the film so that the heated marks remain crystallized after cooling. The phase-change alloy film chemically degrades over time and loses its ability to hold its phase-changed marks, degrading normally in a shorter period of time than the organic dye used in recordable (R) discs. For this reason alone, RW or RAM discs would not normally be considered for archival use compared to R discs. Another reason, by functionality of the disc, is the ability to edit or erase the data and thus the potential to compromise the integrity of the information on the disc.

There is also a limit to the number of times that the phase-change film can be rewritten. RW discs can be rewritten about 1,000 times, RAM discs about 100,000 times. The phase-change film is affected primarily by heat. It is not known how much UV light is a factor in the aging process. The combination of high temperature and UV light however, may accelerate the aging process more than just heat alone. And as with the organic dye in recordable (R) discs, high temperatures and high relative humidity will most likely accelerate the aging process. There have been no lab tests available yet quantifying these environmental effects on rewritable (RW, RAM) discs.

3.3 Metal (Reflective Layer)

The metal layer in optical discs reflects the laser beam back to the laser photosensor in the laser head. There are three types of reflective metals that are typically used for this layer; aluminum, gold, silver or silver alloy. In “double layer” DVDs, silicon is sometimes used as one of the semi-reflective layers.

3.3.1 Metal Layer in ROM and RW discs (CD-ROM, CD-RW, DVD-ROM, DVD-RW, DVD+RW, DVD-RAM)

These discs use aluminum for the reflective layer. Aluminum oxidizes when exposed to the environment or from moisture penetration through the disc. Aluminum is used because it is inexpensive and easy to apply. Some earlier CDs allowed moisture to come into contact with the aluminum metal layer from poor sealing of the disc, causing the aluminum to oxidize. Oxidation of the aluminum diminishes its reflectivity making the disc unreadable by the laser. It is the primary factor for ROM disc degradation due to long-term environmental influences. This is sometimes referred to as disc “rot”. It is not the primary factor for RW and RAM disc degradation. The phase-changing film in these discs normally degrades at a faster rate than the oxidation of the aluminum in the disc.

3.3.2 Metal Layer in R discs (CD-R, DVD-R, DVD+R)

These discs use gold, silver, or a silver alloy for the reflective layer. Silver is slightly more reflective than gold but can lose reflectivity with corrosion if exposed to adverse environmental conditions. Silver reacts, by corrosion, to sulfur dioxide, a pollutant in the environment that can migrate through the disc with moisture. Gold is non-corrosive, very stable, and will last longer but is expensive. Either metal should outlast the dye. Aluminum is not used because it can react with the dye recording (data) layer.

3.3.3 Metal Layers in Double Layer DVD-ROM discs

These discs have two metal layers on the reading side(s) of the disc, one side only or both sides of the disc. This essentially doubles the capacity of the disc. On a double-layered side, one of the metal layers is semi-reflective (silicon, gold, or silver) and allows some of the laser beam to reflect back and some of the laser beam to pass through to a fully reflective layer (aluminum) and then reflect back – both to be detected by the photo-sensor in the laser head.

3.4 Metal Protective Layer (lacquer) on CDs

A very thin lacquer layer is applied to the label side of CDs to provide protection to the metal from exposure to the environment. It also gives some limited protection from writing on or labeling the disc. However, the CD is more sensitive to damage from this side of the disc than the polycarbonate on the data side. Since the metal is so close to the label side surface of a CD, pointed objects or scratches can easily damage the CD by deforming the metal or exposing it to the environment. Some solvents can also affect lacquer coatings and react with or expose the metal. Once the metal is damaged, the laser cannot read data in the damaged areas. Sometimes a manufacture will add an extra layer specifically to add more protection on the label side of CDs. DVDs do not use a protective lacquer coating. Earlier CDs allowed moisture to penetrate the disc to the metal through unprotected areas of the edge. A manufacturing improvement to ensure that the lacquer is applied completely around the edges to seal the disc solved the problem. Thus, it is important to protect the edges of CDs as well as the surfaces.

3.5 Optional additional surface layer

An optional layer may also be added to a CD or DVD to provide a printable surface. (See page 26 for more information about printing on discs)

Types of printable surfaces include:

- Thermal printable surface
- Inkjet printable surface
- Custom screen-printing surface
- A surface that will accommodate more than one type of printing

These layers are applied over the lacquer layer on CDs or over the polycarbonate substrate on a single sided DVD. Some discs have an extra coating that gives the surface the look of text or logos printed on the surface. In many cases, the lettering areas are areas where the extra coating is missing to create the text design, and what you see as text is the reflection of the metal. These areas are comparable to discs without any extra coating and can be seen through when held up to the light, even through the metal. Especially avoid writing or scratching in these areas. This does not include the clear inner hub. Ink or scratches in the hub area will not harm the disc because data is not recorded there. Scratches and writing with a sharp instrument anywhere on the label side surface of a CD (outside the hub area) can easily cause problems where you can see through the disc easily while holding it up to light. This area is most susceptible to damage. Some manufacturers are adding an extra layer just for the purpose of adding protection.

4. How long can you store CDs and DVDs and use them again?

The Life Expectancy (LE) of optical discs is dependent on many factors, some controllable by the user, others not.

Factors that affect disc life expectancy (LE) include:

- Type
- Manufacturing quality
- Condition of the disc before recording
- Quality of the disc recording
- Handling and maintenance
- Environmental conditions imposed

There are three basic types of CD and DVD discs: ROM (read only), R (recordable, also called write-once, read-many), RW and RAM (Rewritable). Each have differing degradation factors that dominates their life expectancies.

The data layer (molded aluminum, organic dye, or phase-change film) in each type of disc is normally the primary cause for disc degradation and ultimately end-of-life for the disc (assuming proper physical handling).

The rate of degradation can be increased or decreased by environmental influences. In each of the three different basic types of discs, environmental factors will degrade the polycarbonate substrate layer (clear plastic that comprises most of the disc) at a much slower rate than the data layer. This relative degradation rate for the polycarbonate layer is so low that it will not be used for life expectancy considerations. Data layer deterioration will render the disc useless well before the polycarbonate deteriorates. Physical mishandling of the disc is usually the cause for polycarbonate layer damage. The polycarbonate may also flex or bend if stored for a long period of time in a position other than vertical.

So what is the life expectancy of a disc? First, we must define life expectancy. For the average user, it would normally mean that the disc is still usable. But that implies some acceptable amount of degradation. Then the next question is, "How much, and what type of degradation is acceptable?"

As mentioned before, all media degrades at some rate. With CDs and DVDs, early degradation is not noticeable to the user because of the error detection and correction capability built into the system. It is only when the error correction fails that degradation, or a problem, becomes noticeable to the user.

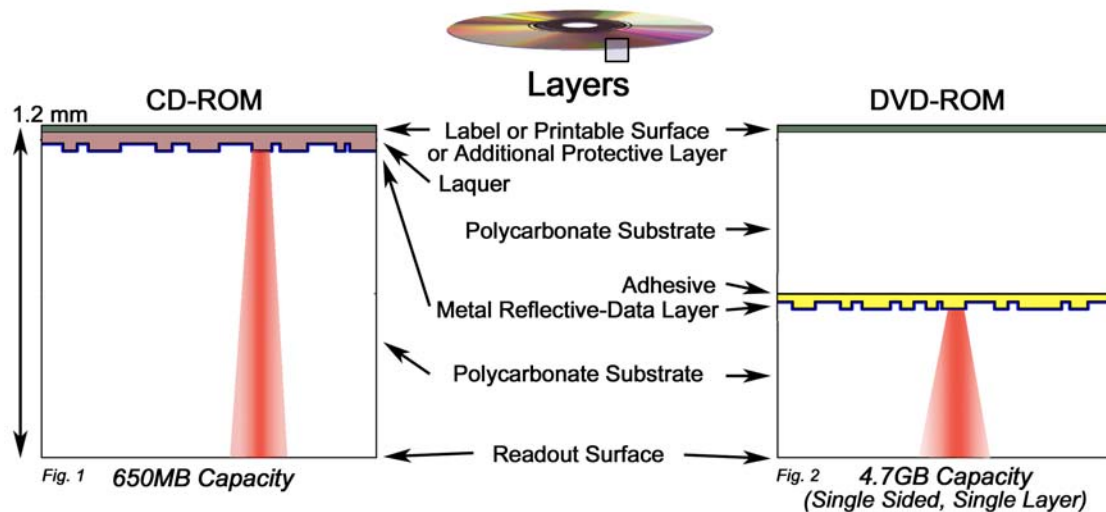
One method for determining the "end-of-life" for a disc is based on the number of errors on a disc. As the number of errors increase, the chance of the disc failing will increase. The error detection and correction coding can correct a certain number of errors before a user will observe degradation in disc performance. Also, it is impossible to define the number of errors in a disc that will absolutely cause a performance problem (minor or catastrophic) because it depends on the error distribution within the data. When the number of errors on a disc increases to a certain level, the chance (even if small) of disc failure at that point can be determined as unacceptable, and thus the end-of-life.

The methods that manufacturers use are essentially based on the above premise, by using accelerated aging methodologies with controlled extreme temperature and humidity influences over a relatively short period of time. However, it is not always clear how a manufacturer interprets their measurements for determining the disc end-of-life. General consensus among manufacturer's claims, that have done testing, is that under recommended storage conditions, 100 years or more is an estimated lifetime for ROM discs, 100 to over 200 years for -R, +R discs, and 25 or more years for -RW, +RW and RAM discs.

There is little, if any, independent laboratory published life expectancy reports for these discs. An accelerated aging study at NIST for one type of DVD-R for Authoring, estimated the life expectancy of that type of DVD-R to be 27 years if stored at 25°C (77°F) and 50% RH. This testing at NIST for R type discs is at the preliminary stages and much more needs to be done.

4.1 CD-ROM, DVD-ROM discs

(Audio, Video, interactive games, +Graphics, computer applications)



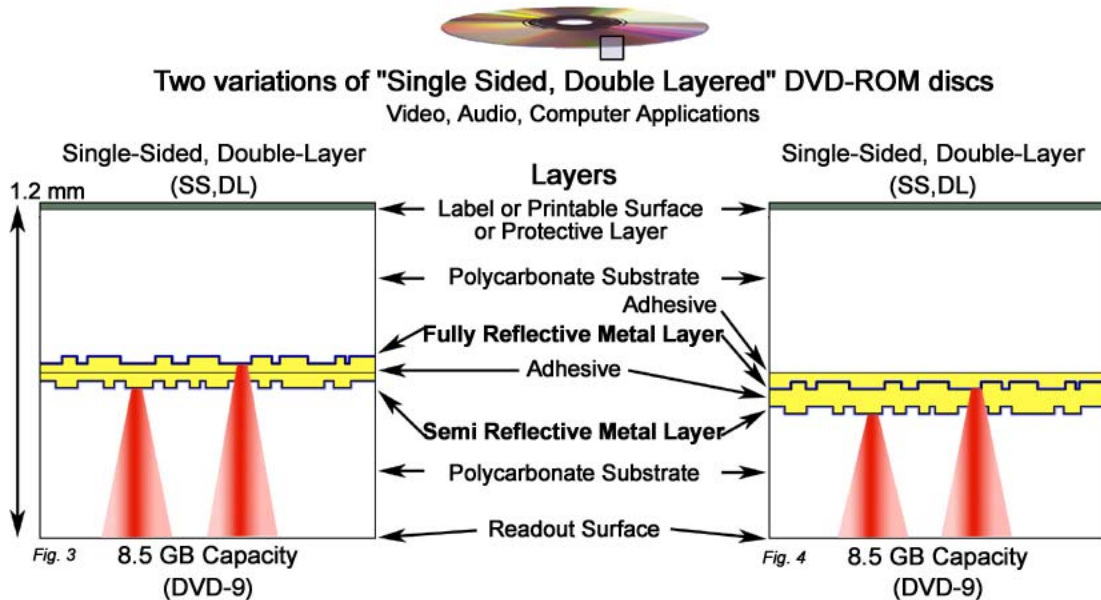
Figures 1, 2: Layers that comprise ROM discs

These discs are similar to each other in that they are replicated discs. The data cannot be erased. It is molded as an integral part of the polycarbonate substrate (plastic) by applying a metal layer (aluminum) to the polycarbonate substrate form on one side during the manufacturing process. These are replicated discs and generally mass-produced. (Figures 1-2)

ROM discs last the longest, or do they? It depends. These are replicated discs typically with music, video, computer applications, or interactive games recorded on them as part of the manufacturing process. The determining environmental factor in this type of disc is the reflective aluminum layer's exposure to oxygen. The metal layer in ROM discs is also considered the data layer because they are integrated together. The pits (depressions) and lands (surface) that form the data are injected and molded by a molding machine into the polycarbonate substrate surface. Metal is then sputtered or condensed onto the molded substrate to form the "reflective-data layer". Oxygen (including pollutants) migrates through the relatively soft polycarbonate layer or the relatively hard lacquer layer (CD label side and edge), carried in by moisture. Oxygen or moisture can more easily penetrate through scratches, cracks, or layer delamination. Oxygen can also be trapped inside the disc during the manufacturing process. Improvements in manufacturing have helped to minimize chances of trapping air bubbles in the disc and to reduce moisture migration through the disc, as mentioned previously, by not only applying the lacquer to the label side, but also completely around the disc edge.

If left in a very humid environment, moisture will penetrate the disc and eventually reach the aluminum. The aluminum loses its reflectivity as a result of oxidation when exposed to oxygen carried in by moisture. The normally shiny (like silver) aluminum becomes oxide-dull and much less reflective (like the color of a typical aluminum ladder).

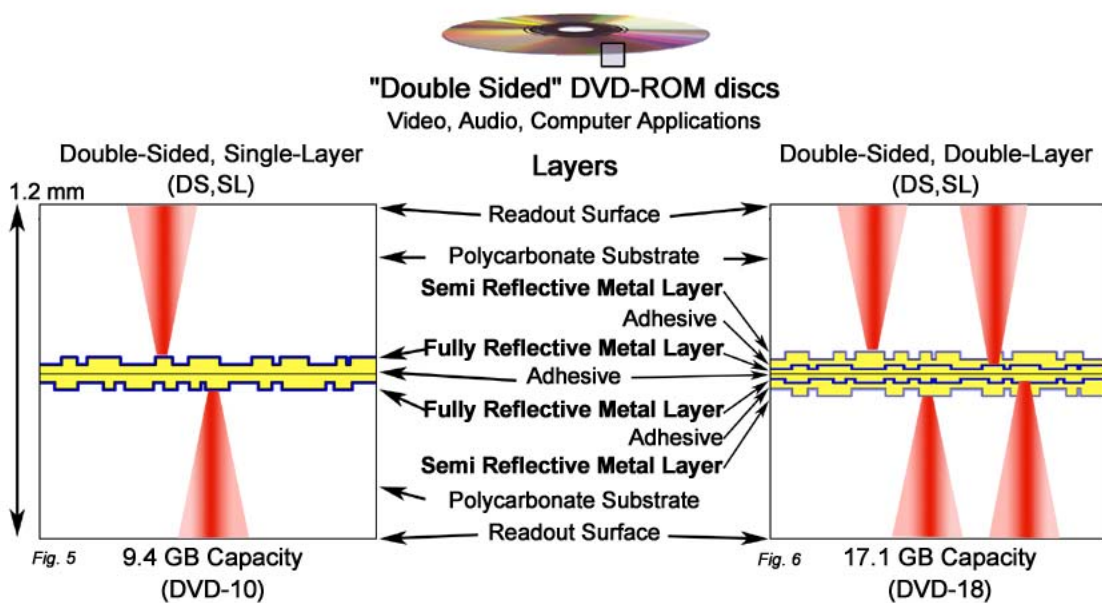
A high temperature and a high relative humidity environment will increase the chances and the rate of oxidation. Life expectancy of a ROM disc therefore depends on environmental conditions it is subject to over time. If the disc is removed from such an environment to an ideal condition before damage has been done, it will “dry-out” and should approach being as playable as if it were in ideal conditions all along. Other contaminants however, such as inks, solvents, and pollutants, have the potential to irreversibly penetrate the disc and deform, discolor, or corrode the disc, causing permanent reading problems by the laser. High humidity is especially problematic by causing oxidation to the reflective aluminum, and increased temperatures accelerate the effect. In general, keep ROM discs in a dry, cool environment.



Figures 3, 4: Two types of Double Layer, Single Sided DVD-ROM construction

DVD-ROMs can be manufactured with two data layers that can be read by the laser from one side. Figure 3 shows the most commonly manufactured construction for single-sided, double-layered DVDs while Figure 4 shows an alternative construction. “Double layered” DVDs provide approximately twice the capacity for content (video, audio, computer applications) than “Single layered” DVDs. The laser beam must pass through a semi-reflective metal layer to read data from a “fully” reflective layer.

The difference between the above two examples of “Single-Sided, Double-Layered” DVDs is that Fig. 3 has the metal-data layers on separate halves of the disc. One laser beam must pass through, in addition to the semi-reflective metal, a special adhesive that does not hinder the laser beam but does bind the two disc halves together. In the example shown in Fig. 4, the two metal-data layers are on the same side (or half) of the disc.



Figures 5, 6: Two types of Double Sided DVD-ROM construction

DVD-ROMs can also be “double-sided”. The example in Fig. 5 shows a double-sided DVD that may typically be a DVD-Video providing the video in a full screen TV version on one side of the disc and a wide-screen version on the other of the disc. Double Sided DVDs have the potential to double again the capacity of the disc as shown in Fig. 6 with the use of double-layers on both sides.

4.2 CD-R, DVD-R, DVD+R discs

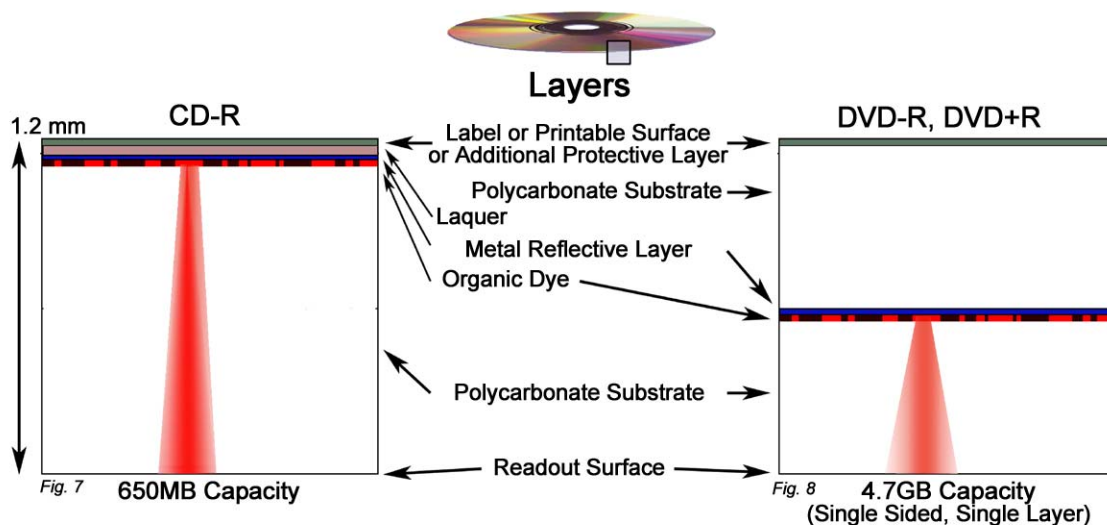
Most optical disc life expectancy tests are preformed with recordable discs (CD-R, DVD-R, DVD+R). These are usually done by manufacturers and categorizing by disc construction type. Manufacturer’s life expectancy claims vary. With proper storage the disc will outlast the technology. These discs use gold, silver, or a silver alloy, for the reflective layer instead of aluminum as in ROM discs. Again, gold will not corrode and but is expensive. Silver is more reflective and cheaper than gold but is susceptible to corrosion if exposed to sulfur dioxide. Sulfur dioxide is a pollutant in the air that can penetrate the disc in the same way oxygen can with moisture. Different silver alloys are used by different manufactures to help inhibit silver corrosion. Keeping the disc in a filtered “clean-air” environment can minimize or eliminate disc exposure to sulfur dioxide. Most recordable discs available today use a silver alloy reflective layer. The chance of the silver corroding due to sulfur dioxide exposure from typical pollution in the air is less than the chance of aluminum oxidizing due to high humidity.

Recordable discs use a dye-based layer (organic dye) for recording data. These are “write once” discs and cannot be erased by CD or DVD drives. The organic dye used in the data layer of recordable (R) discs degrades naturally but slowly over time. High temperatures and humidity will accelerate the process. Prolonged UV light exposure can degrade the dye properties and eventually make the data unreadable. Heat build up

within the disc as a result of sunlight or close proximity to heated light sources will also accelerate dye degradation.

CD-R discs have different color appearances because of the different colors of the dyes combined with the gold or silver metal layer (Table 3, page 8). The disc can have different color from the reading side versus the label side for example, as in the case of gold/green, or silver/blue distinctions. The first color of a color pair refers to the metal, the second color to the dye appearance. One side of the disc will show a color appearance as the result of the dye/metal combination. The other side of the disc will show the color of the metal only, provided no other extra protective or printable layer covers the metal on label side.

(Figures 7,8)



Figures 7, 8: Layers that comprise R discs

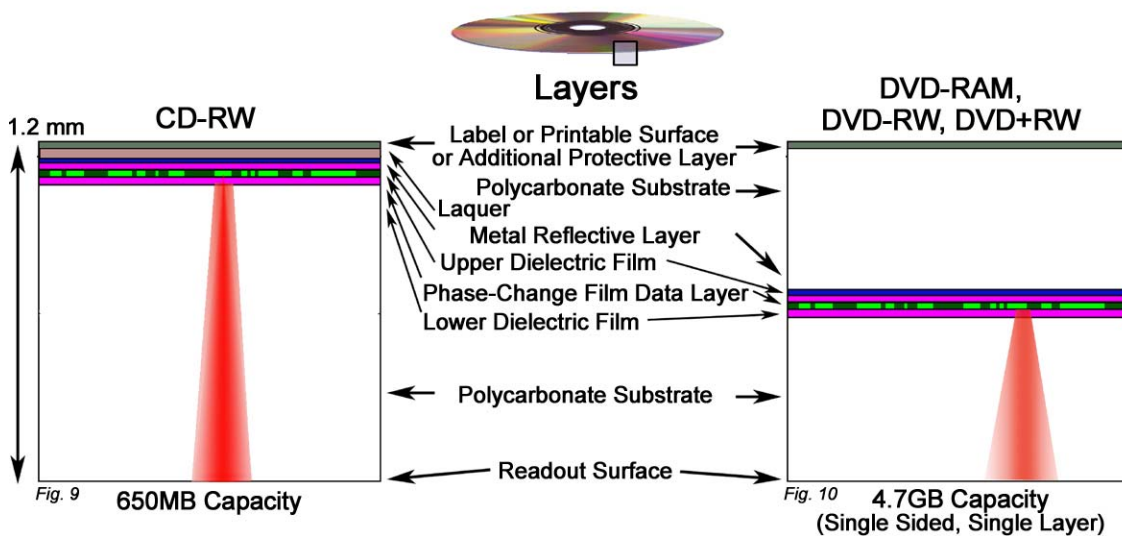
The dye based (R discs) and the phase changing film layers (RW discs) both hold data by allowing or blocking light transfer through the data layer. The laser affected (or “written”) areas of the data layer absorb the “reading” laser beam that is emitted from the laser to the metal layer and reflected back to the laser reading head. The light and dark areas give similar reflectivity effects as the interference effect of the pressed and molded data in the metal/substrate layer in ROM discs. The reflection effect as a result of dye, film, or “pressed” effects are represented digitally as ones and zeros by the firmware in the disc drive as the laser reads the disc.

4.3 CD-RW, DVD-RW, DVD+RW, DVD-RAM discs

RW discs are generally not considered for long-term or archival use. Life expectancy tests are not usually done for this medium. Rewritable discs use a phase-changing metal alloy film for recording data and aluminum for the reflective layer. The phase-changing metal alloy film is not as stable as the dye used in R (recordable) discs because the material normally degrades at a faster rate; however, these discs should still be stable enough to outlast the current CD or DVD technology.

The data on the phase-changing metal alloy film layer can be erased and rewritten to a limited number of times (about 1,000 times for RW discs and about 100,000 times for DVD-RAM discs). If a RW or RAM disc is written to, and archived after the first recording, the recording should have a longer life expectancy than archiving after several erase/recording cycles.

RW and RAM discs allow the possibility of data being written over and either losing or altering information. Information on R (recordable) discs is more secure in this sense because it cannot be changed or rewritten. Life expectancy for RW and RAM discs will be, at the normal natural degradation rate, less than that of R discs.



Figures 9, 10: Layers that comprise RW and RAM discs

5. Conditions that affect CDs and DVDs

CDs and DVDs can be reliable for many decades with proper handling. Degradation is inevitable over a period of time, as with all other types of media but steps can be taken to help prevent it from occurring prematurely. This section lists environmental conditions, handling effects, and how they can impact optical discs.

5.1 Temperature/Relative Humidity

Optical discs will perform well within a wide range of temperature and relative humidity conditions. Discs kept in a cooler, less humid environment, and not subjected to extreme environmental changes should last longer. Optical discs stored in an optimal environment will outlast discs that are not. There are several sources that recommend temperature and relative humidity ranges for storage. (Table 5, page 20)

Archived discs will last longer when stored in a cooler, lower humidity environment. If stored in a very low temperature relative to the user environment, the disc should be gradually acclimated to the environment in which it will be used to reduce stress and moisture condensation. Leave the disc in its packaging to allow gradual acclimation to a changed environment. A large and abrupt temperature change will cause greater stress than a gradual change. Going from a relatively cold environment to a warmer one can cause moisture condensation on the disc.

In general, discs used frequently should be stored at a temperature similar to the environment in which the disc is used. This minimizes stress from frequent temperature changes that may weaken layer bonding.

The benefit to freezing a disc is not known. There are no known tests for storing discs at freezing temperatures. Freezing and thawing CDs or DVDs may create harmful stresses in the disc due to differing expansion rates between the layers. It is not known how much this stress might affect the disc. There may be a benefit to uninterrupted freezing of a disc for an extended period of time. Until testing is done to measure the effects of freeze-thaw cycles or long-term freezing, the benefits or harmful effects are uncertain.

Source	Media	Temperature	Maximum Temp. Gradient	Relative Humidity (RH)	Maximum RH Gradient
ISO TC 171/SC Jan. 2002	CD-R CD-ROM	+5°C to 20°C (41°F to 68°F)	4°C /hr (7°F /hr)	30% to 50%	10% /hr
IT9.25 and ISO 18925 February, 2002	CDs DVDs	-10°C to 23°C (14°F to 73°F)		20% to 50%	Cycling no greater than: ±10%
NARA, FAQ About Optical Media, April, 2001	CDs DVDs	68°F (20°C)	+/- 1°F /day (+/- 0.6°C /day)	40%	5% /day
National Archives of Australia, April, 1999	CDs	18°C to 20°C (64°F to 68°F)		45% to 50%	10% /24 hrs
Library Technical Report Nov.-Dec. 1997	CDs	-10°C to 50°C (16°F to 122°F)		10% to 90%	
DVD Demystified, Second Edition, Jim Taylor, 2001	DVD-R DVD-ROM	-20°C to 50°C (-4°F to 122°F)	15°C /hr (27°F /hr)	5% to 90%	10% /hr
	DVD-RAM	-10°C to 50°C (16°F to 122°F)	10°C /hr (18°F /hr)	3% to 85%	10% /hr
	DVD+RW	-10°C to 55°C (14°F to 131°F)	15°C /hr (27°F /hr)	3% to 90%	10% /hr
National Library of Canada, 1996	CDs	15°C to 20°C (59°F to 68°F)	2°C /24 hrs (9°F /24 hrs)	25% to 45%	5% /24 hrs
Media Services, Inc. Jerome L. Hartke July 2001	CD-R	10°C to 15°C (50°F to 59°F)		20% to 50%	

Table 5: Recommended storage parameters from different sources

5.2 Light Exposure

5.2.1 Light exposure to ROM Discs

The long-term effect of light on ROM discs is not known. The possible effect of long-term exposure to light (UV, sunlight, infrared, fluorescent, and other) under general intensity, like room lighting, on ROM discs is generally thought to be so minimal that light is not considered a factor in the lifetime of the disc. Any effect of light on ROM discs would be to the degradation of the polycarbonate substrate (plastic) that comprises most of the ROM disc and take several decades of daily storage facility lighting before becoming noticeable. This should also be true for indirect sunlight through windows. The degradation effects may likely be in the form of “clouding” or “coloring” of the polycarbonate. To our knowledge, there is no report on the potential impact of this kind of material change on the playability of the disc. Light effects on ROM discs therefore are considered negligible.

5.2.1 Light exposure to CD-R and DVD-R (recordable, or write-once) discs

R (recordable) discs are initially blank discs that can be recorded (written to) but cannot be erased or rewritten over previously written areas. Prolonged exposure to sunlight or other sources of UV light can significantly increase the degradation rate of the recordable dye layer in these discs. Deterioration of the dye makes the pits and lands on the recording layer indistinguishable from each other to the laser sensor, resulting in errors during reading.

Direct sunlight to R (recordable) discs is harmful for two reasons:

1. The sunlight's ultraviolet photons (higher frequency of the sunlight spectrum) have enough energy to produce a photochemical reaction altering the optical properties of the dye (recording layer) molecules.
2. The broad spectrum of unfiltered sunlight, infra-red to ultraviolet (low frequency to high), can be a source of heat to the disc. The increased temperature of the disc, generated by sunlight, accelerates the degradation or breakdown of the dye layer (recording layer) in the disc. The resulting high temperature combined with a high relative humidity will increase the acceleration of the degradation.

The most likely cause of sunlight damage to R discs is a result of the heat when left exposed to the sun. Much of the ultraviolet range of sunlight can be filtered (or absorbed) by glass if a disc is exposed to the sunlight, for example, through a glass window. The effects are, in this case, likely to be more from the lower light frequency range (infra-red) that does more harm by simple heating. If a disc is left exposed to direct sunlight behind a glass window but kept cool in an air-conditioned room, the effects should be minimal, provided the disc itself does not increase in temperature. If the disc is left in a case, or has a label, printing, or added color that allows it to absorb the sunlight, it could have a heat build up that effects the disc. If left exposed to direct sunlight without protection (glass, plastic window), the disc dye will degrade more rapidly. These observations are based on preliminary light effects tests done at NIST.

5.2.3 Light exposure to CD-RW and DVD-RW/+RW/RAM (rewritable) discs

Light should have minimal, if any effect on RW type discs. The phase-changing film that contains the data in these discs is affected by heating. The heat generated from the intense laser beam writes the data in the phase-changing film unlike the photochemical reaction in the writing of R (recordable) discs. The phase changing film used in RW (rewritable) discs is not light sensitive, but the heat effect from direct sunlight is similar to both discs. Heat build-up in RW or RAM discs as a result of direct sunlight will accelerate the phase-changing film degradation rate just as it does to the dye in R type discs. The phase-changing film in RW discs degrades naturally, and from heat build-up by direct sunlight, at a faster rate than the dye in R discs.

CD-R, CD-RW, DVD-R/+R, DVD-RW/+RW, and DVD-RAM discs can become unusable in a matter of days. If left in an environment that allows direct sunlight and extreme heat build up (like leaving the disc on the dash of a car in summer time, or next to a heater by a window), the organic dye or phase-changing film that holds the data will degrade at a very fast rate, causing the disc to become unreadable. Even if the disc is left in a case for protection, if the case is subjected to direct sunlight, heat can build-up within the case and thus the disc. The disc may also become damaged as a result of warping due to the heat build up.

5.3 Surface Handling Effects

Anything on an optical disc surface that interferes with the ability of the laser to focus on the data-layer can result in missing data as the disc is being read. Fingerprints, smudges, scratches, dirt, dust, solvents, excessive moisture, and any other foreign material can interfere with the ability of the laser to read the data. They can also interfere with the ability of the laser to follow data track in the disc. Fingerprints and light scratches are very common; although they both can interfere with laser reading, their effect on the disc is somewhat different.

5.4 Scratches

Scratches affect discs differently depending on which side of the disc they are on and the direction of the scratch. It also depends on the type of disc.

5.4.1 Scratches on the laser-reading side of CDs and DVDs

Scratches generally cross data lines or tracks on the disc, and depending how bad (width and depth) the scratch is, it may not interfere with the laser focusing on the data. Small or occasional scratches will likely have little or no effect on the ability of the laser to read the disc. The laser can still read the data because the focus of the beam is far enough beyond the surface of the disc to read beyond the scratch. This is comparable to a light scratch on a pair of eyeglasses that is not very noticeable because your eyes are focused beyond the scratch. If a scratch is deep or wide enough to affect the laser focus, the error detection and correction coding in the disc drive can recover the missing data in many cases. However, heavy, wide, or multiple scratches close together, can adversely affect the readability of the disc. These scratches can cause the laser to misread enough data that the error correction coding cannot interpolate the original data. Data errors generated from scratches running in the direction from the middle of the disc

outward have a good chance of being corrected by the error correction firmware. Scratches running in a circular direction around the disc are more likely to cause uncorrectable errors (*also called PO Error in the DVD specifications, and E32 in the Red Book for CD specifications*). If a chosen repair method works, scratches may be repaired on the reading side of a disc, but not if the scratch is deep enough to reach the data or metal layers. Once these layers are damaged, the disc cannot be repaired. DVDs are often double sided meaning both sides of the disc are reading sides and potentially repairable (provided the scratch is not too deep). CDs are always readable on one side (can read or read/write data on one side only).

5.4.2 Scratches on the label side of CDs

Scratches on the label side of CD discs can be a more serious problem. This type of damage cannot be repaired. Because the reflective metal layer and data layer is so close to the surface of the label side of the disc, it can be damaged very easily. A slight indentation or pinhole in the metal from a scratch, pen, pencil, ultra fine marker, or other sharp object will destroy the reflectivity of the metal on the other side (laser reading side) and the readability of the data by the laser. Optical disc drives are usually able to read through minor damage easily, especially scratches through the data that radiate from the center of the disc outward. Scratches to the data that follow the direction of the track will usually cause a problem. If the error detection and correction firmware in the disc drive cannot correct the data, it will not be recoverable. Scratches that do not reach through the thin protective lacquer coating should have no immediate affect but may allow moisture or other environmental influences, including pollutants in the air, to reach the metal. Adhesive labels (if applied) may add an extra layer of protection from scratches to the disc surface but may add other adverse conditions as discussed in the “Labels” section. Printable discs have an extra layer that can also add a level of protection from scratches.

5.4.3 Scratches on the label side of single sided DVDs

Scratches on the label side of single sided DVDs are not a problem unless they are extremely deep. The metal layer that is so prone to damage in CD discs is located in the middle of DVD discs. The metal layer has considerably more distance and protection from surface scratches and is unlikely to be affected unless the scratch is deep enough to reach the center of the disc where the metal and data lay.

5.5 Fingerprints, Smudges, Dirt, Dust

Fingerprints, smudges, dirt, or dust on the laser reading side of the disc can interfere with the laser focusing on the data more than a scratch. Dirt or dust on the disc will block or reduce the light intensity of the laser. If severe enough, it will cause the disc drive to miss data as the disc is being read. Fingerprints, smudges, or dirt will not only cross data lines but will cover wide areas of data including along the data lines or tracks (in the reading direction of the laser). Such obstructions will not only cause the laser path to go out of focus or lose intensity, but also cause a more widespread misreading of data along the data lines or tracks, in amounts exceeding the error correction capability in the disc drive. Fingerprints, smudges and dirt are easier to remove than scratches by simply cleaning it off. Dust can also spin off into the disc drive and collect on the laser head or other internal components.

Scratches versus fingerprints and smudges on the disc surface.

(Laser reading side of the disc; data side)

- Occasional fine scratches will typically not affect the focus of the laser.
- Deep scratches can affect the focus of the laser and cause errors.
- The error detection and correction coding system in the disc drive will correct many errors caused by scratches.
- Fingerprints and smudges can cause more errors than scratches and are more likely to overwhelm the error correction coding system capability.
- Scratches going along the reading direction (tangential direction) on a disc are worse than those going from the center of the disc outward (radial direction).
- Several scratches close together can also overwhelm the error correction coding system capability, similarly to fingerprints and smudges.

5.6 Water, Moisture

The polycarbonate substrate, or the “plastic” composition of the disc, is a polymer material. Any prolonged exposure to moisture, a spill, humid air, or immersion, allows water to become absorbed into the polycarbonate substrate where it may react with any of the layers. Returning the disc to a “dry” condition will allow the absorbed moisture or water to dissipate out of the disc over time. Water, or a water-based liquid, may leave behind contaminants such as dyes or other dissolved minerals within the disc. If no permanent damage occurred to the disc while it had absorbed the liquid, the disc should play normally. We have totally submerged a CD into clean water for 24 hours. While the disc was unreadable initially (after removing the disc from the water and allowing the surface to dry), it played normally after 24 hours of “drying out” at approximately 70°F, 50%RH (normal room condition).

5.7 Organic Solvents

Avoid disc contact with strong organic solvents. Harsher solvents such as acetone or benzene will dissolve the polycarbonate and ruin the disc beyond repair. Limited contact (cleaning) with mild solvents (isopropyl alcohol, methanol) is permitted. These solvents evaporate quickly and will not dissolve the polycarbonate. They may however, dissolve or damage labels or optional coatings on the label side of the disc, depending on the material’s reaction to alcohol.

5.8 Markers

Marking and labeling a CD or DVD is an essential process during their creation. CDs and DVDs, or their containers, are labeled in some form or fashion in order for them to be organized and distinguished. When labeling a CD with markers, the contents of the ink in the marker and the style or design of the marker should be considered.

The ink in markers varies in terms of their chemical composition, their pigments or dyes and their solvents that form the ink solution. Markers are divided into three basic categories, water-based, alcohol-based and aromatic solvent-based. The distinction between these three types of markers is the liquid used to form the ink solution. Markers use water, alcohol and aromatic solvents respectively to dissolve the other ingredients

used in ink to form a solution. Within these three main categories, markers are divided even further regarding permanence and ability to write on different surfaces.

Markers also vary in different forms, such as, fine point, extra fine point, rolling ball, ball point, soft felt tip and chisel tip. Some are ideal for CD labeling, while others can cause damage.

Numerous CD vendors have noted that the thin protective lacquer coating has the potential to deteriorate when in contact with certain solvents in markers. For that reason, water-based markers are recommended for CD labeling to virtually eliminate risk. Although alcohol is considered a solvent, it is generally less damaging than xylene and toluene, which are common in aromatic solvent based-markers. There are anecdotal reports of using alcohol-based markers to label CDs without resulting in performance problems. However, there are no lab test results to show what effect solvents in markers have on different CDs or DVDs, particularly in the long-term.

The vulnerability of a CD from the proximity of the data and metal layers to the label side of the disc is also a factor to consider when choosing a marker. These layers are susceptible to damage from scratches or scrapes received from marking the surface. A felt tip marker will minimize the risk of scratching or denting from the marker.

Never use a fine point or rolling ball marker on a CD because of the potential to scratch or depress the surface of a CD and permanently damage the metal and data layers.

Although CDs and DVDs look similar, their layer structures differ. As mentioned before, the recording layer of a CD is located just beneath the labeling side. On a DVD the recording layer is located in the center of the disc. In theory, solvents from a solvent-based marker will not penetrate to the center of a DVD through the polycarbonate layer found on both sides. Consequently, the data and metal layers located in the center, in theory, would not come in contact with any harmful solvents. However, it is recommended to take the same precautions used for labeling CDs. The same marker used to label a CD will work just as well on a DVD. This practice will also eliminate the potential mix up with markers intended for CD or DVD.

A safe investment would be to buy a CD-safe marker sold by numerous vendors. These markers are categorized as water or oil-based by manufacturers, for consumer use on their CDs. Rather than using dyes to give color, these CD safe markers generally contain pigments. The pigment in the ink gives the marker a permanent quality. An alternative is to simply use a water-based felt tip marker. Although these markers guarantee the integrity of one's CD, water-based markers are generally not as permanent as other solvent-based markers. Therefore, a permanent water/oil-based marker is recommended if it is necessary to mark the disc. For risk-free labeling on any disc, use the small inner circle at the center of the disc, referred to as the "mirror band". There is no data in this area of the disc.

5.9 Adhesive Labels

For longer-term storage (more than five years), do not use adhesive labels on optical discs. The label may delaminate over time and interfere with disc drive operation. Any attempts to peel the label off can cause damage to the lacquer and metal layer in CDs. DVDs are different. Peeling a label off a DVD would not have the same adverse affect because the metal layer is not near the surface. Still, if a portion of the label is removed or left on the surface of any disc, it can cause an imbalance while spinning in the disc drive making the disc unreadable. Some earlier labels have been known to have the adhesive react with the lacquer surface. If you receive a disc with an adhesive label already applied to it, and you want to insure the availability of the information for the long-term, make a copy of the disc to store without an adhesive label.

Adhesive labels may be well suited for short-term disc usage (less than five years) and can add an additional layer of protection from scratches and other potentially harmful contact. On the other hand, adhesive labels are subject to environmental conditions where they may dry out, absorb moisture, or be affected by heat or cold more so than the disc itself. Any of these factors may cause the label to delaminate. If you decide to use a label, use only labels manufactured for use on CDs or DVDs and use a disc label applicator tool to apply the label. The label applicator tool should position the label so that it is centered on the disc to provide a balanced spin while in the disc drive. Disc manufacturers advise against using adhesive labels because they may create unbalanced disc spinning resulting in premature wear of the disc drive, or cause damage to the drive from a delaminating label.

5.10 Printable CD-R and DVD-R disc surface

CD-R and DVD-R printer labeling require discs that have a printable surface added to the disc at time of manufacture. The following printing information relates mostly to CD-R but would also apply to DVD-R.

Inkjet printing and thermal transfer printing are commonly used for labeling the surfaces of CD-R discs, each using a different technology to place inks on the printing surface of the disc. Few inkjet printable and thermal printable CD-Rs are interchangeable.

The printable area on a DVD disc depends on whether it is single-sided or double-sided. If the DVD is single-sided, a label may be printed on the top side, like on a CD. However, ink affects the flatness and balance of a disc and is more critical for DVDs than for CDs. Because DVD performance is more sensitive to any imbalance of the disc, full surface printing may not be the best choice. If using full surface printing, whether on CD or DVD, a white base-coat printable surface is available so the colors will not be affected by the metallic appearance of the disc. "Pit art" labeling, as an alternative, avoids the flatness and balance issues. These pits are produced on the label side (without a printable surface added), making a mirrored holograph-like pattern from the metal layer that gives the appearance of a design or a label. Because no ink is used, the flatness and balance of the disc is not compromised.

If a DVD disc has data on both sides (double sided), neither printing nor pit art may be used on the data area of the disc. The area called the "mirror band", and the area between the "mirror band" and center hole may be printed on or marked. (See Figure 11, page 27)

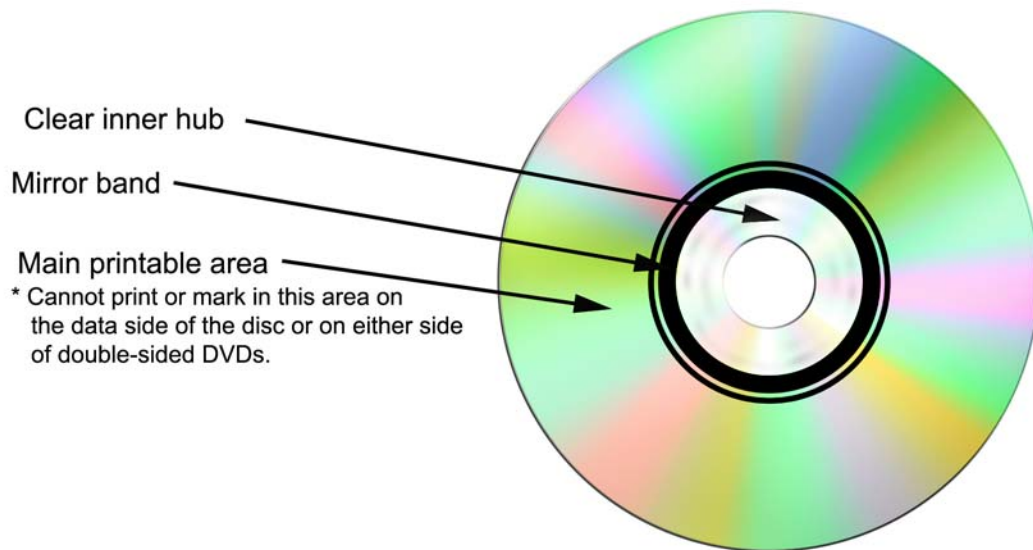


Figure 11, Printable or markable areas of the disc

5.10.1 Thermal printable surface

Only specially designed thermal printers can print directly on the surface of thermal printable CD-R discs. You cannot use a thermal printer designed to print on paper.

In thermal transfer printers, a print head that contains resistive elements in a linear array that heats ink-coated films (ribbons). The head is in direct contact with the uncoated side of the ribbon and the ink-coated side of the ribbon is in direct contact with the disc's printable surface. The ink is heated, causing it to melt and adhere to the printing surface. Specially formulated materials are used for the printable surface of the disc to enhance high ink transfer efficiency and adhesion.

5.10.2 Inkjet printable surface

In inkjet printers, inks are sprayed, via droplets of an ink solution, onto a specially designed printable surface material on the disc. This printable surface material is intended to hold the ink droplets in place while absorbing the liquid components of the ink.

5.10.3 Silkscreening

Silk screening on CDs or DVDs uses a UV curable ink to keep the ink colors from running together. The UV curable ink cannot contain any chemically active components that can affect the disc after the curing process or abrasive particles in the ink pigments that can damage the protective layer of CDs.

5.11 Flexing

Flexing (bending) the disk by removing it from a jewel case, sitting on it, or by any other manner may be harmful to the disc. It may cause stresses and eventual separation between the disc layers. The disc should be stored in its case and placed vertically like books on a shelf. Long-term horizontal storage (particularly in a heated environment) can cause the disc to become permanently bowed. While the data may still be completely intact, the disc may not operate in the drive properly or allow the laser to follow the track. The maximum flex (bend) or number of times a disc can be flexed before it causes damage is not known. To minimize risk of damage, avoid or minimize flexing discs.

5.12 Individual disc storage

Optical discs should be kept in individual storage containers until use and placed back immediately after use. Typical storage containers (as listed below) isolate and help protect discs from airborne contaminants, foreign material, and other objects. They also provide a shield to help buffer rapid environmental changes that can cause stresses to the disc. Cases are designed to keep surfaces of the disc from contact with the inside of the case. Only one disc should be placed on the hub (or each hub) in the case. To remove the disc, press down on the hub tab while holding the outer edges of the disc with your fingers and lift up. Avoid bending the disc while lifting it off the hub tab.

For long-term storage it may be prudent, in some instances, to remove the label insert and/or booklet from inside the case cover and attach it to the outside of the case, in a sleeve for example, before storing the disc. In theory, the paper can attract moisture and cause higher moisture content in the case. The paper may also spread moisture by contact to the disc. There are no tests; however, showing the effects of leaving the paper inside the case. This is just something to consider, especially if there is a thick amount of paper information inside the disc case and humidity conditions are higher than recommended.

Examples of commonly used cases that provide individual disc protection:

5.12.1 Jewel case

The jewel case comes in different varieties. A case holds one to six discs, depending on its design. It typically is a transparent plastic case with a hinged lid, plastic tray(s), inlay card for labeling, and optional booklet.

5.12.2 Slimline case

A slimline case, as the name suggests, is a slimmer version of the Jewel case but without the tray. It uses an inlay card (J-card) and is primarily used for audio discs.

5.12.3 Amaray Case

An Amaray case is a plastic case used for commercially available pre-recorded (replicated) DVD videos and games.

5.12.4 Snapper Case

The snapper case is an alternative case to the Amaray case. A snapper case is a plastic DVD case with a cardboard cover that is snapped shut and held in place by a plastic lip.

5.13 Magnetism, X-rays, Microwaves, and Radiation

- Magnetism should have no effect on CDs or DVDs.
- X-ray exposure (for example, from airport detectors) will not harm optical discs.
- Microwaves in a microwave oven will destroy a disc. (It may also destroy your microwave oven because of the metal in the disc.)
- Radiation-effects test information is currently only available relating to the U.S. Postal Services irradiation of mail to counter bio-terrorism threats. CDs and DVDs have been tested at exposure levels of 60 KGy (Kilogrey's) to 300 KGy of radiation. The discs tested showed no signs of effects on the data; however, the packaging and discs showed some discoloration from the radiation and had a burnt-odor after the test. There were no traces of residual radiation remaining on any of the packages and discs. More information about this testing is available from High-Tech Productions, who conducted the tests, at: <http://www.high-techproductions.com/radiationtesting.htm> (High-Tech Productions, 2002)

5.14 Shelf life – before recording

Manufacturers claim between five to ten years of shelf life before recording on CD-R and DVD-R discs; however, there are no expiration dates written on CD-R or DVD-R/+R packaging. There are no published reports of tests to verify these claims. It would be prudent in light of these claims however, to purchase new discs as they are needed, rather than ordering large quantities to stockpile for future use.

5.15 Wear, from playing the disc

CDs and DVDs do not wear from friction as vinyl records or tapes do. There is no physical contact with the disc in the area that the laser uses.

ROM discs: The laser light will have no effect on the data/metal layer in ROM discs. In theory, it may be possible for the disc to be read so many times that the cumulative effect of the laser light can eventually affect the polycarbonate, but it is negligible.

R discs: Each time the laser reads an R disc; the laser can have some minimal effect on the recording layer and polycarbonate. In theory, R discs should have a limited number of read times because of the cumulative effect on the data layer from the laser light. The polycarbonate, as mentioned for ROM discs, may also (in theory) eventually be affected.

We do not know of any instances where these discs have been played so many times as to cause damage from the laser light. Any effects from the laser light in ROM or R discs should be so incredibly small as to be considered negligible. The disc will fail from some other condition before it is played enough times to fail from the disc drive laser light.

RW discs: Rewritable (RW) discs however, can “wear-out”. CD-RW and DVD-RW discs should last for about 1000 re-writes before the re-writing capability is worn out, 100,000 times for DVD-RAM. The reading functionality of the disc should continue for a limited number of read times after each writing. The maximum number of read times possible after writing is unknown and may become less after each successive writing.

6. Cleaning

Try to do as little cleaning as possible to CDs or DVDs. CDs and DVDs do not require a regular or routine maintenance cleaning.

Clean the disc only when it is ABSOLUTELY necessary.

Clean optical discs:

- before storing when surface contamination is visible.
- before recording when surface contamination is visible.
- before playing when surface contamination may “fling off” while the disc is spinning in the disc drive.
- when readability (playability) is impaired and surface contamination is visible.

In general, avoid using organic solvents. Harsher solvents (acetone, benzene) will dissolve the polycarbonate and ruin the disc beyond repair. Mild solvents (isopropyl alcohol, methanol) however, are okay to use. These mild alcohol solvents evaporate quickly and will not dissolve the polycarbonate.

Other examples of solutions that are not harmful are water-based lens cleaners or water-based detergents (with mild soap) formulated for cleaning CDs or DVDs.

The polycarbonate substrate is a relatively soft and transparent type of plastic. Each time the disc is wiped, rubbed, has a solution applied to it, or otherwise “treated”, you run the risk of scratching or contaminating the disc.

Tips to remember if the disc needs cleaning.

- Use an air puffer to blow off dust.
- Use a soft cotton cloth or chamois to wipe the disc.
- Try cleaning with a dry cloth first, before using any cleaning solutions.
- Do not wipe in a circular direction.
- Wipe from the center of the disc towards the outer edge.
- Avoid using paper products to wipe the disc, including lens paper.
- Avoid using anything abrasive on the surface of the disc.
- If the disc has a heavy accumulation of dirt, try rinsing with water first.
- Use commercially available water-based detergent formulated for cleaning the surface of optical discs, or
- Use isopropyl alcohol or methanol to clean the surface as an alternate to water-based detergents.

CD			
<ul style="list-style-type: none"> CD discs are single sided (One recorded layer or recordable layer on one side of the disc) 			
Disc	Type	Storage Capacity	Typical Uses
CD-ROM, Audio-CD, Video-CD	Read only	650MB	Commercially available: computer programs, music
CD-R	Record once	650MB	User recording music, computer data, files, applications
CD-R	Record once	700MB	
CD-RW	Rewritable	650MB	User recording computer data, files, applications
CD-RW	Rewritable	700MB	

DVD			
<ul style="list-style-type: none"> DVD-ROM, DVD-Video (commercially available pre-recorded DVDs), can be single or double sided with one or two data layers on one or both sides of the disc (a maximum total of four data layers). DVD-R, DVD+R, DVD-RW, DVD+RW, are only available as single sided, single layer (SS/SL). DVD-RAM is available in double-sided, single-layer (DS/SL). 			
Disc	Type	Storage Capacity	Typical Uses
DVD-ROM, DVD-Video, DVD-Audio			Commercially available: Movies Interactive games, Programs, Applications
Single side has one data layer (SS/SL)	Read only	4.7GB	
Single side has two data layers (SS/DL)	Read only	8.54GB	
Both sides have one data layer (DS/SL)	Read only	9.4GB	
Both sides have two data layers (DS/DL)	Read only	17.08GB	
DVD-R (General)	Record once	4.7GB	General use: One time video recording and data archiving
DVD-R (Authoring)	Record once	3.95GB or 4.7GB	Professional use: Video recording and editing
DVD+R	Record once	4.7GB	General use: One time video recording and data archiving
DVD-RW	Rewritable	4.7GB	General use: Video recording and PC back-up
DVD+RW	Rewritable	4.7GB	General use: Video recording and editing, data storage, PC back-up
DVD-RAM			Computer data: Storage repository for updateable computer data, back-ups
Single-sided	Rewritable	2.6GB or 4.7GB	
Double-sided	Rewritable	5.2GB or 9.4GB	

Table 6: Current commercially available CD/DVD disc types
See Glossary for definition of above terms

Disc Type ↓	* DVD drive types and what they can do with each disc type											
	DVD ROM Play only (computer)		DVD-R (General) Records General -R		DVD-R (Authoring) Records Authoring -R		DVD-RW Records -RW, General -R		DVD-RAM Records RAM		DVD+R/+RW Records +R, +RW	
	Read	Write	Read	Write	Read	Write	Read	Write	Read	Write	Read	Write
DVD-ROM	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
DVD-R (General)	U	No	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	No
DVD-R (Authoring)	U	No	Yes	No	Yes	Yes	Yes	No	Yes	No	Yes	No
DVD-RW	U	No	Yes	No	Yes	No	Yes	Yes	U	No	U	No
DVD-RAM	R	No	No	No	No	No	No	No	Yes	Yes	No	No
DVD+R	U	No	U	No	U	No	U	No	U	No	Yes	Yes
DVD+RW	U	No	U	No	U	No	U	No	U	No	Yes	Yes
CD-ROM	Yes	No	Yes	No	No	No	Yes	No	U	No	Yes	No
CD-R	Yes	No	Yes	Yes	No	No	Yes	Yes	U	No	Yes	Yes
CD-RW	Yes	No	Yes	No	No	No	Yes	Yes	U	No	Yes	Yes
	U = Usually R = Rarely											
DVD-Video DVD-Audio	All DVD drives should play DVD-Video or DVD-Audio if the computer has DVD-Video or DVD-Audio player software installed. DVD-RAM drives are questionable.											
* Most computer DVD drives are backward compatible to CDs, meaning they can read or read/write CDs. * Some drives are the combination of more than one drive type, providing compatibility with different DVD and CD disc types.												

Disc Type ↓	CD drive types and what they can do with each disc type					
	CD ROM Play only		CD-RW or CD-R/RW Records –RW, -R		CD-R Records -R	
	Read	Write	Read	Write	Read	Write
CD-ROM	Yes	No	Yes	No	Yes	No
CD-R	Yes	No	Yes	Yes	Yes	Yes
CD-RW	Yes	No	Yes	Yes	No	No
DVD-Video, Audio DVD-ROM DVD-R (General) DVD-R (Authoring) DVD-RW DVD-RAM DVD+R DVD+RW	----- DVDs do not work in CD drives or CD players. -----					

Disc Type ↓	Home DVD Video Player compatibility with each disc type	
	DVD Video Player	Comment
DVD-Video DVD-Audio	Plays	- DVD-Video and DVD-Audio are a type of DVD-ROM commonly used in home DVD-Video or DVD-Audio players. - Use of the term DVD-ROM, typically refers to replicated (commercially available pre-recorded) DVD-ROMs for computer applications.
DVD-ROM DVD-RAM	N/A	
DVD-R (General) DVD-R (Authoring) DVD-RW, DVD+R, DVD+RW	Depends	If the disc is formatted correctly, it should play in newer home DVD Video players.
CD-ROM (Video-CD)	Depends	If the CD-ROM, CD-R, or CD-RW are formatted as V-CD, (Video-CD), some DVD Video players will play them (some DVD players compatible with MPEG 1).
CD-ROM (Audio-CD)	Plays	
CD-R (V-CD or audio formatted)	Usually	
CD-RW (V-CD or audio formatted)		

Table 7: DVD Drive types and how they handle different disc types

7. Glossary

Analog (content and storage media):

- Analog content: Content that uses a mechanism in which data is represented by continuously variable physical quantities (examples: frequency and amplitude of sound recorded on tape, image printed on film).
- Analog storage media: Stores analog content (examples: paper, photographic paper or negative, film, microfilm, audio tape, VHS tape, vinyl records, stone, cave wall)

To be used in computers, analog content must first be converted into a binary code. Analog content converted into binary code (digital content) is often referred to as "digitized". "Digitizing" is the "sampling" of an analog signal or content at predetermined interval locations and then converted into binary (1,0) form (digital). The closer the intervals, the more closely the digital signal represents the analog signal.

Amaray case:

A plastic case normally used for commercially available pre-recorded DVD videos and games.

Archivist:

A person in charge of archives administration, including preservation.

Archive:

- (1) To file, collect, or store materials or media in an archive, or archive collection for preservation.
- (2) A place where materials are preserved.

Audio CD, Also, CD-DA (CD-Digital Audio), CD-A (CD-Audio):

The audio format was implemented to hold about 60 minutes of audio data, in up to 99 tracks (songs) to produce high quality stereo sound. The success of audio CD (or CD-Digital Audio) has been key for the growth and success of CD-ROM and other CD formats.

Bit:

The 1 or 0 that represents the smallest piece of data (binary information having the elements 0 and 1). Bits are used mostly when dealing with bandwidth rates (bits/sec), graphics resolutions, and related topics.

Byte:

A string of 8 bits, operated upon as a unit. Bytes are typically used as a measure of file size or storage capacity.

CD (Compact Disc):

An optical disc. CD is a term loosely applied when describing a variety of compact disc formats, from the production (mass produced) audio and data discs, to the write once "recordable" versions (CD-R) or write many "rewritable" versions (CD-RW) CDs. The standard CD disc can hold about 650MB of data on a single disc.

CD+G (Compact disc plus graphics):

Primarily used for karaoke. A variation of CD, which embeds graphical data in with the audio data, allowing video pictures to be displayed periodically as music is played. A special player is needed to read and display the information.

CD-I (Compact Disc - interactive):

A compact disc format designed to allow interactive multimedia applications (digital audio and video, video games, and software applications) to be run on a player attached to a television.

CD-R (Compact Disc - Recordable):

CD-R is a version of CD on which data can be recorded but not erased. Uses an organic dye-based material to hold data that is written to by a laser.

CD-ROM (Compact Disc - Read Only Memory):

A standard for compact disc to be used as digital memory media for personal computers.

CD-ROM Drive:

A peripheral device attached to a computer, which allows it to read/play a CD-ROM disc. All CD-ROM players can also play back audio CDs, but you need external headphones or speakers to hear them.

CD-RW, (Compact Disc - ReWritable):

CD that allows the user to erase previously recorded information and then to record new information onto the same physical location on the disc. CD-RW media can only be written in a CD-RW recorder, not in a CD-R recorder, though a CD-RW recorder can also record CD-R discs.

Content:

Audio, video, photographic images, graphics, interactive games, computer applications, documents, files, databases, etc.; understandable information made up from data stored in a digital format.

Copy:

(noun) Content that has been read from a source medium and written to another medium or to a separate space on the same medium.

(verb) To read data from a source, leaving the source data unchanged at the source, and to write the same data elsewhere, though they may be in a physical form that differs from that of the source.

Data:

Pieces of information from which “understandable information” is derived. For purposes of this guide; the bits (1, 0) recorded in the disc, from which applications or understandable information are derived.

Data Area:

The space on a CD or DVD where the digital content is located.

Data layer:

The layer on an optical disc that holds data as marks of conditions within the layer. These represent the data on the disc and either absorb or transmit the laser light reflected back to the laser photosensor.

Dielectric layer:

A layer on both sides of the phase changing film data layer in rewritable CDs and DVDs (RW and RAM) that rapidly cools the phase changing film, allowing heated marks to remain crystallized.

Digital:

The binary coding scheme generally used in computer technology to represent data as binary bits (1s and 0s). Digital information is generally contrasted to analog information. Analog information can be digitized by sampling.

Double layered DVD:

A DVD that has two metal data layers allowing for twice the storage capacity over single layered DVDs.

Disc Drive:

A computer or player device that reads, or reads and writes, specific moving storage discs.

DVD:

(Once stood for Digital Video Disc or Digital Versatile Disc, now just DVD)

The next generation of optical disc storage technology after the CD. Same physical size and shape as a Compact Disc (CD) but has a higher data density and optionally, double sided or double layered recording.

DVD-Audio:

Audio-only storage format similar to CD-Audio, however offers 16, 20 and 24-bit samples at a variety of sampling rates from 44.1 to 192KHz, compared to 16 bits and 44.1KHz for CDs. DVD-Audio discs can also contain music videos, graphics and other information.

DVD-R (DVD – Recordable), (Sometimes referred to as: DVD minus R):

DVD-R is a version of DVD on which data can be recorded, but not erased, by a disc drive. Uses an organic dye-based material to hold data that is written to by a laser. DVD-R provides secure recording for volumes of information that cannot be accidentally or intentionally altered. There are two versions of DVD-R:

- **DVD-R (A) (DVD-Recordable for Authoring):**
Format for professional content developers and software producers. Primarily used to create master discs that will be mass-produced by software houses, multimedia/video postproduction facilities and archiving.
- **DVD-R (G) (DVD-Recordable for General use):**
For general recording of all types of content; audio, video recording, and data recording. Compatible with most DVD-Video players and DVD-ROM drives.

DVD+R (DVD plus Recordable):

For general recording of all types of content; audio, video recording, and data recording. Compatible with most DVD-Video players and DVD-ROM drives.

- **DVD-R, DVD+R (differences):**

(Either type is suitable for most applications.)

- DVD+R uses a different technique from DVD-R in how the laser follows the disc track while writing data to the disc. A writer disc-drive is generally capable of writing to one type of disc but some may be capable of writing to both types. All DVD drives should read both DVD-R and DVD+R.
- DVD-R uses constant linear velocity (CLV) for the disc rotation; DVD+R can use CLV or constant angular velocity (CAV) for the disc rotation. CAV allows for easier random access of data on the disc.
- DVD+R can provide lossless linking of new data added from multiple recording sessions.

DVD-RAM (DVD - Random Access Memory):

A Rewritable DVD. It is a cartridge-based, and more recently, bare optical disc technology for data recording and playback. Current DVD-ROM drives and DVD-Video players cannot read DVD-RAM media. Data can be recorded and erased up to 100,000 times. DVD RAM uses a phase-change data layer to record data written to it by a laser.

DVD-ROM (Read Only Memory):

Optical disc is used for storing data, interactive sequences, audio, and video. DVD-ROMs run in DVD-ROM, DVD-R, DVD-RW, or DVD-RAM drives, not DVD-Video players connected to TVs and home theaters. However, most DVD-ROM drives will play DVD-Video movies, if the associated software is installed in the computer.

DVD-RW (Sometimes referred to as: DVD minus RW), (DVD - ReWritable):

Officially referred to as "re-recordable" format by the DVD Forum, but is commonly known as rewritable format. For general recording of all types of content; audio, video recording and editing, and random data recording. Compatible with most DVD-Video players and DVD-ROM drives.

DVD+RW (DVD plus RW), (DVD - ReWritable):

For general recording of all types of content; for audio, video recording and editing, and random data recording. Compatible with most DVD-Video players and DVD-ROM drives.

- **DVD-RW, DVD+RW (differences):**

(Either type is suitable for most applications.)

- DVD+RW uses a different technique from DVD-RW in how the laser follows the disc track while writing data to the disc. A writer disc-drive is generally capable of writing to one type of disc but some may be capable of writing to both types. Most newer DVD drives should read both DVD-RW and DVD+RW.
- DVD-RW uses constant linear velocity (CLV) for the disc rotation; DVD+RW can use CLV or constant angular velocity (CAV) for the disc rotation. CAV allows for easier random access of data on the disc.
- DVD+RW can provide lossless linking of new data inserted or added from multiple recording sessions.

DVD Video:

Popular format for high quality MPEG2 or MPEG4 video and digital surround sound. Enables multilanguage, multisubtitling and other advanced user features.

Emulation Technology:

Software or hardware that gives a device the ability to mimic the characteristics of another device. This allows newer devices or software to interoperate with older devices, software, or media because the newer device or software operates in a manner that is understandable by the older device or software.

Format:

Pre-established layout for data.

Hub:

This is the area about the central hole of the optical disc-- it is also called clamping area. The spindle of the drive clamps the disc by this hub, which should fit rather precisely to provide reliable centering and eliminate flutter as it transfers the rotational movement imparted by the motor. For obvious reasons, this area must be kept clean to prevent any slippage. While CD products use this area for serial number and other replication plant production codes, double-sided DVDs will use it for identification information as well.

Information:

Meaningful expression or interpretation of data.

Jewel case:

A plastic case commonly used to hold CDs and some DVDs. Usually a clear plastic case with hinged lid, plastic tray(s) to hold CDs or DVDs, inlay card for labeling, and can include a booklet in the front of the case.

Lacquer layer:

A very thin layer on CDs designed to protect the metal layer from exposure to the environment. It also provides limited protection allowing writing on or labeling of the disc.

Laser photosensor:

A component of an optical disc drive that senses whether or not it is receiving laser light of a particular frequency with a detectable intensity.

Layer:

A thickness or course over or under another thickness or course within a disc.

Life Expectancy (LE):

When the useful life of a disc is considered over as a result of a failure in the disc. Failures in the disc that determine life expectancy are generally measured by causes from physical stresses or chemical reactions resulting from environmental exposure.

Mark:

Low reflectance feature of a recording layer representing data that can be sensed by an optical system.

Media:

Plural of medium

Medium:

Material on which data are or may be recorded, such as paper, punched cards, magnetic tapes, magnetic disks, or optical discs (examples: CD, DVD).

Metal layer:

The layer in optical discs that reflects the laser beam back to the laser photosensor. Aluminum, gold, silver, or silver alloy are generally used depending on the type of disc.

Mirror band:

Slender ring of highly reflective silver, which extends from the outer edge of the clear inner hub at 38mm to the inner edge of the main printable area of the disc at 46mm.

Optical Disc:

A disc that is 'written' (encoded) and 'read' using a laser optical device. A flat, circular, plastic disc that contains a highly reflective metal and uses bits to represent data by containing areas that alter (reduce) the effect of reflectance when illuminated with a narrow-beam source, such as a laser diode. The bits (data) are stored sequentially on a continuous spiral track starting from near the center of the disc and going to the outer edge.

Original:

The first representation or generation of given content or object.

Organic Dye (dye polymer):

Photosensitive organic chemical; located between the polycarbonate substrate and metal layers and makes up the data layer of a recordable CD or DVD. The organic chemical changes reflectivity (darkens) when exposed to intense light (laser) of a particular wavelength.

Oxide-dull:

The less reflective state of a metal (for example: aluminum) caused by oxidization.

Oxidization:

A chemical reaction between oxygen and another substance, causing the original substance to have its properties altered. In the case of aluminum, oxidization reduces its reflectivity.

Phase-changing film:

A metal alloy (silver, indium, antimony, and tellurium). It is sandwiched between two dielectric layers and located between the polycarbonate substrate and metal layers. It is the data layer of rewritable (RW and RAM) CDs and DVDs. Data is written to this layer after a laser beam heats the film causing crystallization (a phase change) to occur. The crystallization remains intact due to rapid cooling caused by a dielectric layer on both sides of the film.

Photochemical reaction:

The chemical reaction in CD-R and DVD-R discs resulting from the interaction of the organic dye and laser light. The interaction results in a change of property of the organic dye in the areas exposed to the laser light. These areas are known as bits or data that have been "written" into the organic dye.

Playback system:

Computer with a CD or DVD drive, DVD player, CD player, interactive game system or karaoke system, that uses optical discs are all examples of an optical disc playback system.

Polycarbonate substrate:

Transparent physical layer that comprises most of an optical disc. It also provides mechanical support through which the laser can access an information layer.

Pre-recorded disc:

Replicated disc. Also called ROM disc. Generally, commercially available discs with the content recorded on them during the manufacturing process.

Preservation:

(The definition is slightly adapted from the National Archives and Records Administration)

Preservation encompasses the activities that prolong the usable life of materials. Preservation activities are designed to minimize the physical and chemical deterioration of materials and to prevent the loss of informational content. These activities include providing a stable environment for materials of all media types, using safe handling and storage methods, duplicating unstable materials (e.g. nitrate film, thermofax) to stable media, copying potentially fragile materials into a usable format (e.g. microfilming or digitization), storing materials in housings made from stable materials (for example, document boxes made from "acid-free" paperboard), repairing documents to maintain their original format, establishing a pest control program and instituting a disaster recovery plan which includes plans for emergency preparedness and response.

Pressed Discs:

These discs are mass produced replicated discs, (commercially available pre-recorded discs, examples: audio CDs and video DVDs). The data in these discs is molded as an integral part of the polycarbonate substrate during the manufacturing process by applying a metal layer (aluminum) to the side of the polycarbonate substrate containing the "land/bit" form. Also called ROM or Replicated disc.

Read:

An operation that results in the flow of data from an object (CD, DVD) to a subject (CD Drive, DVD Drive).

Record:

To write data on a medium, such as magnetic tape, magnetic disk, or optical disc.

Recordable:

Media (examples: CD-R, DVD-R/+R, CD-RW, DVD-RW/+RW, DVD-RAM) that data can be written to by a drive that can write to the media. In the case of CD-R, DVD-R, and DVD+R, the R stands for recordable, but not rewritable, meaning the disc can only be recorded or written to a particular area of the disc one time, and can not be re-recorded, rewritten, or modified over that same area. Depending on how the disc was finalized when recorded, the unrecorded area of the disc is often not recordable after any portion of the disc has been recorded.

For this document, recordable refers to write-once, or R discs and rewritable refers to “RW discs (re-recordable (write, erase - write again)).

Red Book for CD specifications:

Document developed by Sony and Philips in 1980 that provides the first specifications for standard compact disc (CD).

Reflectance (Reflectivity):

Proportion of incident light that is returned from a reflective surface.

Removable Storage:

Media (examples: CDs and DVDs) or hardware, used for storing data (content) that is easily removable from its associated hardware and stored separately from the associated hardware.

Replicated disc:

Generally, commercially available disc with the content recorded on it during the manufacturing process. Also called ROM disc.

Rewritable:

Recordable storage medium that can be overwritten multiple times, normally without pre-erasure. CD followed by the –RW notation, or DVD followed by –RW, +RW, or –RAM notation. (CD-RW, DVD-RW, DVD+RW, DVD-RAM). The RW indicates rewritable disc.

RH:

Relative Humidity

ROM:

Read only memory. Generally, commercially available disc with the content recorded on it during the manufacturing process. Also called replicated disc.

Single sided:

Data can be read or written to (recordable discs) from one side of the disc only.

Single layered DVD:

A DVD that contains only one metal and data layer, on one side, or both sides.

Slimline case:

A slimmer version of the jewel case. Unlike the jewel case it does not contain the plastic tray, instead using an inlay card (J-card). Primarily used for audio discs.

Snapper case:

A plastic DVD case with cardboard cover that is snapped shut and held in place by a plastic lip. An alternative to the Amaray case for storage of pre-recorded DVDs.

Storage:

Retrievable retention of data. Electronic, electrostatic, electrical, hardware or other elements (media) into which data may be entered, and from which data may be retrieved, as desired. A facility or place that houses the above.

Storing:

The action of holding something (CDs, DVDs) in storage.

UV light:

Light found between the end of the visible light spectrum (violet, 400nm wavelength) and the beginning of the X-ray spectrum (100nm wavelength). Common sources include solar rays and florescent black lights.

Video CD (V-CD):

A standard for displaying full motion pictures with associated audio on CD. The video and sound are compressed together using the MPEG 1 standard, and recorded onto a CD Bridge disc.

WORM:

“Write-Once-Read-Many” recording on non-erasable blank media that contain pre-stamped grooves to guide a write laser.

Write:

Record data onto a recordable or rewritable media from a disc drive.

Write-once:

Recordable storage medium that cannot be erased or re-written. Optical disc examples are: CD followed by the –R notation, or DVD followed by –R, or +R notation. (CD-R, DVD-R, DVD+R). The R indicates recordable disc.

References:

BC Archival Preservation Service, Optical Disk Media, AABC Newsletter, Volume 11 No. 3, Summer 2001

CD-R & CD-RW Questions & Answers

OSTA-4, Revision 2.00, 15 July 97

OPTICAL STORAGE TECHNOLOGY ASSOCIATION (OSTA)

<http://www.osta.org/technology/cdqa.htm>

Chris Anglim, Technical Services Law Librarian, Volume 22, No. 4 (June 1997), Preserving The CD-ROM, South Texas College of Law

CNET Networks, Inc.

Care and feeding of CD-Rs, 2002

<http://computers.cnet.com/hardware/0-1091-8-8020643-6.html?tag=st.co.1091-8-8020643-1.txt.1091-8-8020643-6>

Disc Anatomy

<http://computers.cnet.com/hardware/0-1091-8-8020643-5.html?tag=st.co.1091-8-8020643-1.txt.1091-8-8020643-5>

Compact Discs: Permanence and Irretrievability May Be Synonymous In Libraries As Well As In Roget's, Mary E. Marshall and Ginni Voedisch, OCLC, Online Computer Library Center, Inc., 1990

Conservation OnLine (CoOL), NARA/Long-Term Usability of Optical Media, March 2001

<http://palimpsest.stanford.edu/bytopic/electronic-records/electronic-storage-media/critiss.html>

Customizing CDs, The CD-Info Company, 1997

<http://www.cd-info.com/cdic/technology/cd-r/labeling/> - 2002

Daniel R. Campbell, Digital Preservation Strategies, What's Good. What's Bad. What Should You Do? AALL Spectrum, December 2000

Defense Technical Information Center (DTIC), Digest, Nonprint Media Update: Longevity and Optical Media, 2002

<http://www.dtic.mil/dtic/digest/digest2001-1/Nonprintmed.html>

DVD Club Review, DVD Care and Handling, 2001

<http://www.dvd-club-review.com/dvdguidecare.htm>

Eastman Kodak Company

Handling Kodak CD-R Media, <http://www.kodak.com/cluster/global/en/service/tib/tib4356.shtml>

Labeling Kodak CD-R Media, <http://www.kodak.com/global/en/service/tib/tib4298.shtml>

Permanence, Care, and Handling of CDs, 2001

<http://www.kodak.com/cluster/global/en/professional/products/storage/pcd/techInfo/permanence.jhtml>

Eastman Kodak Company, Permanence and Handling of CDs, updated September 2001

<http://www.kodak.com/global/en/professional/products/storage/pcd/techInfo/permanence1.jhtml?id=0.3.6.30.17.6&lc=en>

- CD Types
- Nature of CD-ROM
- When is a CD's life Over?
- How Long Can CDs Last?
- Safe Handling
- Storage Conditions
- CD Permanence in Perspective

Douglas Stinson, Fred Ameli, and Nick Zaino, The CD-Info Company, Inc., Digital & Applied Imaging, Lifetime of KODAK Writable CD and Photo CD Media, 1995

<http://www.cd-info.com/CDIC/Technology/CD-R/Media/Kodak.html>

F.Frey, S. Susstrunk, Digital Photography – How long Will It last?
ISCAS 200 – IEEE International Symposium on Circuits and Systems, May 28-31, 2000

Graham Sharpless, Disctronics Manufacturing Ltd,
CD and DVD Disc Manufacturing, January 2002
http://www.disctronics.co.uk/downloads/tech_docs/replication.pdf
DVD: An Introduction, January 2002
http://www.disctronics.co.uk/downloads/tech_docs/dvdintro.pdf
Introduction to CD and CD-ROM, January 2002
http://www.disctronics.co.uk/downloads/tech_docs/cdintroduction.pdf

High-Tech Productions, Postal Service selects Titan to eradicate Bio-Threat in U.S.

Mail. High-Tech Productions to conduct Media Testing with Titan. 2002
<http://www.high-techproductions.com/radiationtesting.htm>

Imation Corporation, Care and Handling Instructions, 2002
Handle with Care: Making Your CD-R & CD-RW Media Last, 2002

International Standard ISO 18921, Imaging materials – Compact discs (CD-ROM) – Method for estimating the life expectancy based on the effects of temperature and relative humidity, 2002

Jerome L. Hartke,
CD-R Media Survey, Media Sciences, Inc., May 22, 2000, <http://www.msscience.com/survey.html>
Measures of CD-R Longevity, Media Sciences, Inc., July 17, 2001, <http://www.msscience.com/longev.html>
Why CD-Rs Fail, Medialine, October 2002

Jim Taylor,
DVD Demystified, Second Edition, 2001
DVD FAQ, <http://www.dvddemystified.com/dvdfaq.html>

Dr. John W.C. Van Bogart, Long-Term Preservation of Digital Materials, National Media Laboratory, 1996

Katherine Cochrane, Recordable CD and DVD for Archiving, 1998
(Originally published in Microscopy Today, No.98-10 (Dec 1998))
<http://www.cd-info.com/CDIC/Applications/Archiving.html>

Ken Pohlman, The Compact Disc Handbook, 2nd Edition, 1992

Kusato Hirota and Gentaro Ohbayashi, Reliability of the Phase Change Optical Disc, Toray Industries, Inc, Electronic and Imaging Materials Research Laboratories, 1997

Kyong-Ho Lee, Oliver Slattery, Richang Lu, Xiao Tang, and Victor McCrary, The State of the Art and Practice in Digital Preservation, NIST, IITL, CISD, 2002

Library of Congress (LOC)

National Digital Information Infrastructure and Preservation Program
<http://www.digitalpreservation.gov/ndiipp/>

Maxell Corporation of America, Tech Info, 2002
<http://maxell-data.com/techinfo/whitepapers/>

Maxell, Maxell DVD R White Paper, 2002
http://www.maxell-data.com/techinfo/whitepapers/dvd-r_white.shtml

Media Sciences, Inc., Frequently Asked Questions, 2002
<http://www.msscience.com/faq.html>

Michael W. Gilbert, Digital Media Life Expectancy and Care, UMass Office of Information Technologies, Fall 1998

Mitsui Advanced Media Inc.

Mitsui DVD-R, 2002

http://www.mitsuicdr.com/technology/technical_papers/documents/DVD-R_information.pdf

CD-R Dyes: How to tell what's what, 2002

<http://www.mitsuicdrstore.com/Dyes.htm>

Silver vs. Gold: Which is best for me?, 2002

<http://www.mitsuicdrstore.com/silver&gold.htm>

Handling Instructions, 2002

http://www.mitsuicdrstore.com/handling_instructions.pdf

NARA, Frequently Asked Questions About Optical Media, April 2001

<http://www.nara.gov/records/fags/optical.html>

National Archives and Records Administration (NARA),

Frequently Asked Questions About Optical Media, 2001

http://www.archives.gov/records_management/policy_and_guidance/frequently_asked_questions_optical.html

National Library of Australia,

Preserving Access to Digital Information (PADI), Optical Discs, 2002,

<http://www.nla.gov.au/padi/topics/53.html>

Protecting and handling optical discs, April 1999,

<http://www.naa.gov.au/recordkeeping/rkpubs/advices/advice6.html>

National Library Of Canada, Gilles St-Laurent, The Care and Handling of Recorded Sound Materials, 1996, Gilles St-Laurent, Music Division

<http://palimpsest.stanford.edu/byauth/st-laurent/care.html>

National Institute of Standards and Technology, Information Technology Laboratory, 895-4, DVD and Data Storage Research, <http://www.itl.nist.gov/div895/>

PCTechGuide,

STORAGE/CD-ROM, 2002, <http://www.pctechguide.com/08cd-rom.htm>

STORAGE/CD-RECORDABLE/CD-REWRITABLE, 2002, <http://www.pctechguide.com/09cdr-rw.htm>

STORAGE/DVD, 2002, <http://www.pctechguide.com/10dvd.htm>

Peter Z. Adeltein, Permanence of Digital Information, International Conference of the Round Table on Archives XXXIV – CITRA Budapest 1999

Pioneer Electronics Service, Inc., CD Care and Information, Doc No. 14038

Ron Kushnier, Chairman Compact Disc – Reliability & Integrity of Media Working Group of The Special Interst Group on CD-ROM Applications and Technology, Code 5053, Naval Air Warfare Center, Care And Handling Of CD-ROM Discs,

SANYO Laser Products, Inc.,

DVD – Frequently Asked Questions, 2002

<http://www.sanyolaserproducts.com/dvd/faq.htm>

Sony Electronics Inc., Care and Handling: CD-R and CD-RW, 1997

<http://www.sel.sony.com/SEL/rmeg/mediatech/care/careCD/html>

TDK , TDK CD-R Technology, 1999

Technical Advisory Service for Images (TASI),

An Introduction to Digital Preservation, March 2002, <http://www.tasi.ac.uk/advice/delivering/pdf/digpres.pdf>
Using CD-R and DVD-R for digital preservation

Tim Clatterbuck, Choose CD-R, CD-RW media as though your data life depends on it, International Journal of Micrographics & Optical Technology, Volume 17, Number 4, 1999

Titan Corporation San Diego, Organic Consumers Association, Effects of Electronic Beam Irradiation on Nonfood Substances, Initial Beam Effects Summary

U.S. Department of Agriculture, National Agricultural Library, Carol Ditzler, Caroline Early and Claudia Weston, The Electronic Information Initiative, Phase 1 Final Report, Revision 3, Chapter 7 - Preservation Issues for Optical Media, October 1994
http://www.nal.usda.gov/services_and_products/other_nal_products/eii/nal-eii7.html

Verbatim Corporation, FAQ, What is the proper care and handling for optical discs?, 2002
<http://www.verbatim.com/products/products.cfm?showfaq=16&search=1>

William Saffady, Stability and Care of Microfilms, Magnetic Media and Optical Disks, Library Technology Reports, Nov. – Dec. 1997